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THE MOVEMENT TOWARDS "PHYSIOLOGICAL" PSYCHOLOGY. I

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LIKE many words of broad sweep and intensive significance, the term "soul" has descended to us laden with centuries of righteousness—and iniquity. Even yet some folk roll it as a sweet morsel under the tongue; while others, seeing it is neither hot nor cold, would spew it from their mouths forthwith. Consequently, whereas the very title "psychology" means a study of the soul, to-day one seldom hears the too suggestive name inside a psychological laboratory, for there we have no inclination to the *double entendre*. And the impression has gone abroad that this altered attitude dates from very recent times. Accordingly, it is necessary to point out, first, that traces of a psychology rooted in physiology, that is, of psychology as a natural science, did not begin yesterday, indeed, they may be said to antedate physiology itself. Thus, while it may be needless to consider Pythagoras's alleged discovery, that the tones in an octave are results of relations between physiological movements capable of numerical measurement, or Aristotle's extraordinary prevision, of the study of ψυχή as a matter for the physiologist,[1] we can not omit reference to post-Renascence thought.

As happens so often, especially when a recent movement attains its heyday, the "heroes before Agamemnon" are apt to be robbed of all credit. Flushed by the success of experimental methods, some have tended to forget that the forerunners did but what they could. To accuse them of interrogating themselves "without information, experience, apparatus, or means of procedure,"[2] to blame them for their inexactness and mysticism, or for their subservience to preconceived beliefs, to individual fancies and predilections, is to evince lack of

[1] *De Anima*, I., i., 403ᵃ, 25.

[2] "German Psychology of To-day," Th. Ribot, p. 5 (Eng. trans.).

historical sense. They groped in the dim, grey dawn of science, without our advantages, but they set the problems which we attack hopefully in the bright glow of early morning. If, then, we remember this, we shall be less surprised to learn that, leaving many lesser lights aside, at least two dozen men, between Locke (1690) and Lewes (1860), play their preparatory parts to Fechner, Wundt and the devoted contemporary group of psychological coworkers. To make this clearer, let me adduce some names, adding the approximate dates of most significant activity. Locke, 1690; Berkeley, 1709; Lavatar, 1772; Kant, 1781; Herder, 1785; Galvani, 1786; Cabanis, 1801; Volta, 1801; Gall, 1805; Spurzheim, 1813; Young, 1807; Sir Charles Bell, 1811; George Combe, 1820; Herbart, 1825; Fourier, 1825; Js. Müller, 1835; Beneke, 1835; E. H. Weber, 1846; du Bois Reymond, 1848; Lotze, 1852; Helmholtz, 1856; Bain, 1857; Lewes, 1860; Fechner, 1860; Wundt (1874), the inheritor of all this renown, who, in a manner parallels for psychology Darwin's position in natural history.

Our next task is to unravel the tangled skein of investigation and tentative hypotheses, of discovery and unsolved problems, for which these names stand. This is no easy thing, because some of the threads can not be disentangled. But we may contrive to render the situation less puzzling, and so see how we came to stand where we have been for the past twenty years.

Premising that they cross, recross, and even coincide occasionally, three lines of development may be traced. These are: *First,* the philosophical, in the accepted sense of this term, which originates, of course, in a view of human experience as a whole, or, restricting the compass somewhat, emphasizes the gross organization of consciousness; *second,* the physical, which lays stress on the relation of certain events in consciousness to objects presented under the primary conditions of space and time; *third,* the physiological, which founds on the interconnection between conscious processes and the structures of the body, particularly the cerebro-spinal system. As every one knows, the first appeared earliest, while the second and third, being dependent upon the advance of positive science, had to await what we may call the Newtonian and genetic epochs, the one initiated by Copernicus, the other by Herder and Schelling. Till the age of Kant, philosophy and physics are dominated by British thought, all things considered; from Kant till the first quarter of the nineteenth century French thought acquired increased importance; thereafter, the primacy passed to Germany, where it still remains, the influence of Darwinian ideas aside (and so I shall omit reference to the later British school). For, physiology and physiological psychology, along with the problems issuing from the new outlook, are German products in the main. The synthesis of information constituting the modern science of consciousness was "made in Germany."

I

The point of departure, then, lies in the philosophical line. Little as he could foresee the future influence of his theory, Locke raised, in a manner, the entire question of the relation between consciousness and the physiological organism by his famous distinction between the primary and secondary qualities of body.[3] Qualities like color, odor, hardness and sound, he called secondary, because they can not become effective components of consciousness unless the appropriate organs cooperate. Neither color nor sound resides in nature, but motions of such and such amplitude. For us, therefore, color and sound happen to be interpretations by eye and ear of something incommensurable with the perceptions *in* consciousness. On the contrary, qualities such as resistance and extension belong to objects in their own right, and persist independent of any cooperation by our sense organs. Locke did not grasp the philosophical problems involved here, much less the extreme complexity of the physiological processes he assumed. However, he does advert to one of the difficulties embedded in his view—the "mystery," as it remains even yet, of space perception:

> I shall here insert a problem of that very ingenious and studious promoter of real knowledge, the learned and worthy Mr. Molineux, which he was pleased to send me in a letter some months since; and it is this:—"Suppose a man *born* blind, and now adult, and taught by his *touch* to distinguish between a cube and a sphere of the same metal, and nighly of the same bigness, so as to tell, when he felt one and the other, which is the cube, which the sphere. Suppose then the cube and the sphere placed on a table, and the blind man be made to see: *quaere*, whether *by his sight, before he touched them*, he could now distinguish and tell which is the globe, which the cube?" To which the acute and judicious proposer answers, "Not. For, though he has obtained the experience of how a globe, how a cube affects his touch, yet he has not yet obtained the experience that what affects his touch so or so, must affect his sight so or so; or that a protuberant angle in the cube, that pressed his hand unequally, shall appear to his eye as it does in the cube."—I agree with this thinking gentleman, whom I am proud to call my friend, in his answer to this problem; and am of opinion that the blind man, at first sight, would not be able with certainty to say which was the globe, which the cube, whilst he only saw them; though he could unerringly name them by his touch, and certainly distinguish them by the difference of their figures felt. This I have set down, and leave with my reader, as an occasion for him to consider how much he may be beholden to experience, improvement and acquired notions, where he thinks he had not the least use of, or help from them.[4]

As the last sentence indicates, this reference remains incidental rather than determining for Locke.

It was left for his successor and critic Berkeley to give special form to the problem for its own sake, in his "Essay towards a New Theory of Vision" (1709). With remarkable prescience, he writes:

> Rightly to conceive the business in hand, we must carefully distinguish

[3] "Essay concerning Human Understanding," Bk. II.; Chap. VIII.

[4] "Essay concerning Human Understanding," Bk. II., Chap. IX., Sect. 8.

between the ideas of sight and touch, between the visible and tangible eye; for certainly on the tangible eye nothing either is or seems to be painted. Again, the visible eye, as well as all other visible objects, hath been shown to exist only in the mind; which, perceiving its own ideas, and comparing them together, does call some pictures in respect to others. What hath been said, being rightly comprehended and laid together, does, I think, afford a full and genuine explanation of the erect appearance of objects—which phenomenon, I must confess, I do not see how it can be explained by any theories of vision hitherto made public. In treating of these things, the use of language is apt to occasion some obscurity and confusion, and create in us wrong ideas. For, language, being accommodated to the common notions and prejudices of men, it is scarce possible to deliver the naked and precise truth, without great circumlocution, impropriety, and (to an unwary reader) seeming contradictions.[5]

That is to say, Berkeley insists upon the necessity for another and more concrete analysis than that afforded by the resources of descriptive language.

Later, in "The Principles of Human Knowledge," Part I., he seems to indicate that this profounder analysis must take a physiological direction:

The philosophic consideration of motion doth not imply the being of an *absolute Space*, distinct from that which is perceived by sense, and related to bodies. . . . When I excite a motion in some part of my body, if it be free or without resistance, I say there is *Space*. But if I find a resistance, then I say there is *Body:* and in proportion as the resistance to motion is lesser or greater, I say the space is more or less *pure*. . . . When, therefore, supposing all the world to be annihilated besides my own body, I say there still remains *pure Space;* thereby nothing else is meant but only that I conceive it possible for the limbs of my body to be moved on all sides without the least resistance: but if that too were annihilated then there could be no motion, and consequently no Space.[6]

Knowing little of physiology, Berkeley leaves the problem, stated so far, indeed, but only stated. It is this: How can we derive space, a general condition of external objects, from states of the body which, in their very nature, differ utterly from this, their product? Twenty-two years later, he returns to the question, and appears to raise it in fresh form. In the Fourth Dialogue of "Alciphron, the Minute Philosopher," he says:

(Euphranor speaks:) "We perceive distance, not immediately, but by mediation of a sign, which hath no likeness to it, or necessary connection with it, but only suggests it from repeated experience, as words do things." (Alciphron replies:) "Hold, Euphranor: now I think of it, the writers in optics tell us of an angle made by the two optic axes, where they meet in the visible point or object; which angle, the obtuser it is the nearer it shows the object to be, and by how much the acuter, by so much the farther off; and this from a necessary demonstrable connection."[7]

It is needless to add that Berkeley, although he makes physiological reference and research inevitable, lived long before such a study of "local signs" as that undertaken by Lotze was practicable.

[5] Sects. 119–20. [6] Sect. 116. [7] Sect. 8.

Thus, the "mystery" is simply held over, to be attacked by Kant, in whose person eighteenth century thought was to give place to a very contrasted movement. For him, space and time, the general forms of human perception of all events in consciousness, are factors not derived from materials supplied by sensation. They belong to the unifying power of perception in its relation to objects which, again, demands the presence of elements presented by sensation. Accordingly, he is quite clear that, for example, geometrical truth must be classed as *a priori;* that is, it can not be distilled, as it were, from those sense materials acquired in the course of experience. Thus Kant forces us to class him as a "nativist." So it does not surprise us to observe that he fails to envisage difficulties which were to become capital for physiological psychology at a later time. For instance: How, as a matter of fact, do we construct our completed perception of space? Granted that it be the product of psychical processes, what are they? Granted that it become effective only in the presence of objects, which presuppose sensuous matter, What does this physiological reference gift to our perception? Or, once more, by what subtle alchemy can we explain the obvious fact that we distribute our sensations in space, as it were? How, that is, can we account for localization? Here we quit the philosophical line for a while, observing that its unanswered questions will reappear in an altered perspective.

II

In the realm of physics, prior to the systematic inquiries of the nineteenth century, several more or less sporadic references to the connection between physical and psychical phenomena occur. Such, for example, were the discussions, by Euler and Daniel Bernouilli, of "the law governing the motions of strings";[8] Bernouilli's theory of the *mensura sortis,*[9] with Laplace's addition of the *fortune physique* and the *fortune morale.* These forecast the laws of psycho-physical relationship formulated by E. H. Weber and Fechner. Similarly, the discoveries of Galvani and Volta led to speculations on a supposed parallelism between the known phenomena of electricity and the so-called "discharges" of innervation which, in a way, plumbed the depths of quasi-charlatanism in the developments from Mesmer, and touched the heights of scientific advance in du Bois Reymond's classical work "Untersuchungen über thierische Electricität" (1848), where the mystical and the physical views passed over into physiology for systematic clarification.

Again, Fourier's Law, that "any given regular periodic form of vibration can always be produced by the addition of simple vibrations, having vibrational numbers which are once, twice, thrice, four times,

[8] "The Sensations of Tone," Helmholtz, p. 23 (Eng. trans.).

[9] "German Psychology of To-day," Ribot, p. 226 (Eng. trans.).

etc., as great as the vibrational number of the given motion";[10] Ohm's analysis of the "periodic motions perceived by the human ear,"[11] and Wheatstone's stereoscope united to demonstrate that the psychical and the physical stand in close connection.

Finally, Young's color-theory, with its three primary colors—red, green and violet—paved the way for a passage from physical to physiological considerations; for it led to the hypothesis of "specific energies" in the nerve-fibers.

Ere we pass to the epoch-making transformations of last century, two movements, discredited in many ways it is true, yet of importance as preparatory, demand recognition. It may surprise us to find that they are phrenology and physiognomy. Gall and Spurzheim, both physicians, substituted for the descriptive and introspective faculty-psychology an anatomical scheme parallel essentially in result. They concluded that the faculties can be localized in definite portions of the brain, and that these, in turn, can be traced by reference to the surface formation of the skull. Phrenology created wide-spread interest early in the nineteenth century—witness George Combe (1828) in Edinburgh, who, it may be interesting to relate, received a call to the chair of philosophy in the University of Michigan, or Caldwell and Godman in this country. Through a long series of fluctuating fortunes their suggestions became effective finally as elements in a scientific physiological psychology when Broca (1861) located the brain-center of speech; and, ever since, thanks to the labors of Hughlings Jackson, Ferrier, Golz, Hitzig and many others, this has provided an important sphere of study to physiological psychology.

In similar fashion, the observations, opinions and speculations of Lavatar, in his "Physiognomische Fragmente" (1772), produced a *furore;* elicited Sir Charles Bell's famous "Essay on the Anatomy of Expression" (1806), with its theory of the relation between intellectual power and the facial angle; and, at last, attained complete scientific consecration in Darwin's masterly book, "Expressions of the Emotions in Man and Animals" (1872).[12] Thus positive error and misleading half-truth sometimes serve to state problems which, otherwise, might have failed to gain hearing. One may conclude fairly, then, that questions about the relation of body to mind were in the air throughout the entire course of the eighteenth century and, at its close, had begun to become clamant.

III

At this juncture philosophical activity assumed unprecedented proportions and left a solid deposit destined to a constructive influence

[10] Helmholtz, *loc. cit.*, p. 52.

[11] Cf. *ibid.*, pp. 23, 51, 89, 102–3.

[12] Cf. "Physiol. Psych.," Wundt, Vol. II., pp. 598 f. (4th ed.).

which, I fear, too few scientific men realize to-day. The years 1780–1840 witnessed an efflorescence of speculative thought unparalleled in western history save once—in that wonderful century (422–322 B. C.) when Socrates, Plato and Aristotle secured for the Greeks a far more permanent and formative hold over mankind than was ever achieved by Aristotle's amazing pupil, Alexander the Great. As at Athens, so in the modern period, transitive intellectual personages are legion. Here it must suffice to mention Herder, Fichte, Schelling, Hegel, Herbart and Beneke. Fichte's previsions of a social science, Schelling's wide-spread sway over nascent physiology and medicine, and Hegel's splendid mission, as founder of contemporary critico-historical and comparative studies that have altered the face of human nature, must be suppressed now. But, for psychology, Herder, Herbart and Beneke present matter of high import.

Herder possessed that rarest of endowments, a seminal mind. His thought scattered seeds everywhere, which have come to fruitage since in philology, comparative religion, anthropology and psychology, to name no others. Genetic conceptions inspired him, and his command of enormous reading enabled him to illustrate them concretely, if sporadically. Under the influence of Albrecht von Haller, the eminent Göttingen naturalist, who founded experimental and brain physiology,[13] he foresaw the necessity of physiological research for psychology. "According to my thinking," he wrote, as early as 1778, "there is no psychology possible which is not at every step definite physiology. Haller's physiological work once raised to psychology, and, like Pygmalion's statue, enlivened with mind, we shall be able to say something of thought and sensation."[14] No less remarkable is the following, in its prophetic insight; "Among millions of creatures whatever could preserve itself abides, and still after the lapse of thousands of years remains in the great harmonious order. Wild animals and tame, carnivorous and graminivorous insects, birds, fishes and man are adapted to each other."[15]

But, admitting Herder's vision to the full, his main title to a distinct place in the historical line of psychologists supplies the reason why, strange as it may seem, we must dismiss him briefly in the present context. The most recondite and, at the same time, most potent quality of self-consciousness roots in its eerie power of objectification. Students brood upon this increasingly, sciences like historical criticism, sociology and æsthetics offering testimony. Men bandy words about the "social mind," about "mob psychology," about a "national or epochal *ethos*," and so forth. Customs and institutions, myth and religion yield paleontological records, not of individual men, but rather of

[13] Cf. "The History of Physiology," Foster, pp. 291 ff.

[14] Cf. "Vom Erkennen und Empfinden der menschlichen Seele," Werke, IX.

[15] Quoted by Sully in the Encyc. Brit. (9th ed.), Vol. XI., *s. v.* Herder.

humanity, a kind of compost of individuals. But the implications hinted here receive their most striking manifestation in language. Now Herder, to give him his due, must be saluted as the herald of *Völkerpsychologie* and of *Sprachwissenschaft*. So he stands aside from the line under examination. For, even if it be recalled that phonology can be classed as a physiological science, the matter terminates there. Great as have been the contributions of W. von Humboldt, Bopp, Grimm, Max Müller and their coworkers, and much as has been accomplished by Waitz, Lazarus, Steinthal, McLennan, Spencer, Lubbock, Tylor, Frazer and Westermarck, all sit more or less loose to physiological psychology, which continues an investigation of individual far more than of group processes. So, attractive and suggestive as Herder is, perforce we rest content now with the bare reference to what I have had the temerity to call his seminal mind.

When we arrive at Herbart and Beneke the case presents a different aspect. For they stand forth among the last great psychologists who deal with mind as mind, to the exclusion of modern experimental methods applicable chiefly to the body. After a manner their services pale in the glow of the contemporary atmosphere; their work has been bemused by pedagogists, misprized overmuch by psychologists, even if, as Wundt says,[16] he owes most to Kant and Herbart, and even remembering the work of Herbartians like Drobisch, Volkmann, Exner, Strümpell, Cornelius and R. Zimmermann.[17]

Note, at the outset, that Herbart (1776–1841) and Beneke (1798–1854) revolt strongly against the dominant Hegelian school, and that both attempt a *concrete* study of consciousness. On one point they differ decisively. Herbart's psychology, as the title of his chief work runs—"Psychology as a Science, founded, for the first time, upon Experience, Metaphysics and Mathematics," possesses a triple basis. Beneke excludes the second and third, emphasizing experience as the sole legitimate foundation. In this respect he takes the pioneer place among those who raised the later cry, "Back to Kant!"

Thanks to the limits of this paper, Herbart's metaphysical doctrine must disappear with a word. He held that the soul, in its own proper nature, forms an original, changeless and simple entity. Psychological processes originate in its resistance to intrusion from the outside, therefore, the complexities of consciousness, just because they are *complex*, fall within the reach of analysis. As results of mechanical interaction they lie open to mathematical methods. Such procedure, of course, leads straight to experience, and, on the whole, it may be affirmed that, as his psychology prospers, the direct influence of his metaphysic wanes. In this way a long step towards psychology viewed

[16] "Physiol. Psychologie," preface to the first edition, 1874.

[17] Cf. *Mind*, Vol. XIV., pp. 353 ff. (old series).

as a natural science becomes easy. Let us try to see how Herbart presaged such tendencies.

He denies that consciousness consists in a bunch of faculties. Mind persists as a system of concrete relations between its constituent parts. These parts interact mutually, and therefore stand in mechanical relations to one another. As thus related, they constitute a unity of "presentation" which *resists* "arrest of any of its components." Accordingly, "presentations" may form series; these series, in turn, may arrest or strengthen, and shorten or intertwine, mutually. While the simple substance of soul (metaphysical) remains unknown qualitatively, its activities, in its processes of self-maintenance, afford the states of consciousness which psychology studies. In this respect the soul happens to be identical with all other "reals" which, in sum, make Herbart's universe. Therefore, methods peculiar to the positive sciences find application, and mathematical analysis becomes a chief instrument of discovery. Further, the opposition between "presentations" transforms states of consciousness into forces, with the result that a statics and dynamics (mechanics) of mind emerge. It is feasible, accordingly, to *calculate* the equilibrium and movement of "presentations." So, conformably to science, Herbart frames hypotheses and tries to establish them by mathematical methods. He sets himself to show *accurately* how the indeterminate manifold of sensation, as envisaged by Kant, and the multiplicity of ideas as set forth by the faculty-psychology, come to an organic unity in appercipient self-consciousness. In a word, the proper study of psychology is mind which, in turn, consists precisely in those transforming processes known collectively as "apperception." A very apposite delimitation of the psychological field, one would add. And it is both interesting and important to note that, in this theory of apperception, above all else, Herbart continues to speak in contemporary psychological thought. His connection with the modern movement, though by no means clear on the whole, appears in special tendencies. First, in his complete acceptance of the method of regressive analysis; second, in his appeal to experience; third, in the attention which he has compelled to the possibility of mathematical applications in this unstable sphere; fourth, in his gradual drift away from his own metaphysical basis as he wrought to render psychology a natural science—to prove that, in mind, as everywhere, natural law reigns supreme.

Notwithstanding all this, his opposition to anything in the nature of a physiological psychology seems certain. For this curious hesitation reasons must be sought, not in any antagonism peculiar to Herbart himself, as some recent experimental enthusiasts, blind to history, have fondly supposed, but in the general perspective of his age. Like many of his followers, he was a partisan enemy of the speculative philosophy that ruled Germany, and he paid the inevitable price. His judgment

on certain scientific developments became warped. He perceived that Schelling's "Naturphilosophie" exercised profound influence upon much of biological science as it then stood. Physiology looked like an ally of idealism, therefore he would exclude it rigidly from psychology, as a sure source of trans-experiential contamination. On this he spoke with no uncertain sound—physiology, as he saw it, was no fit friend for a mathematico-empirical psychology. "Physiology, as an empirical doctrine, has attained a height which nobody can despise. Moreover it proceeds in the light of modern physics. Nevertheless, it has eagerly sucked up, as the sponge sucks up water, that philosophy of nature which knows nothing, because it began by construing the universe *a priori*. Towards this error no science has proved so weak, so little capable of resistance, as physiology."[18] The very end for which Herbart toiled so strenuously is obscured from him by his suspicion of physiological tendencies. Truly the time-spirit plays us humans queer tricks!

Free from these negative considerations, Beneke brought psychology another stage nearer science. He excluded Herbart's metaphysic, demanded concrete treatment of consciousness as the one road to real knowledge, and placed all the other philosophical disciplines in a position of dependence upon psychology. His pivotal doctrine exhibits clearly the possibility of scientific procedure in psychology. It may be put as follows. Experience presents two sides—an "outer" and an "inner." The former consists of sensational phenomena, or, as Hume would have said, "sensations, passions and emotions as they make their first appearance in the soul." The latter includes everything that relates to memory, imagination, thought and ratiocination. Thus science, which deals with the "outer," reaches indirect knowledge of being, while psychology, thanks to its immediate contact with its object ("inner"), arrives at knowledge of true reality. Consequently, by analogy from our own selfhood, we can acquire relatively sufficient knowledge of other men, this sufficiency dwindling, so to speak, as we descend in the scale of existence. Accordingly, positive science is confined to observation, but psychology considers knowledge—an inference from this same observation. Therefore the methods of science apply as much in the one sphere as in the other. In short, consciousness originates the dualism between soul and body, mind and objects. Corporeal processes become conscious in us, and thus fall under direct perception:

> There is no kind of corporeal process which can not under certain circumstances become conscious, and as a conscious thing be perceived by us directly. . . . Such a revolutionary change of a thing usually not a psychical apprehension to a psychical apprehension, would be unthinkable were it the case that their being was in fundamental opposition: we are thus led all the more to the conclusion that both kinds of powers in their innermost nature stand very close

[18] "Werke," VI., p. 65.

to one another, and that for the explanation of their inner coherence and interaction no artificial hypotheses are requisite.[19]

Evidently, then, psychology investigates all that we apprehend through internal perception. If we apprehend anything by external perception, it must submit to transmutation by the "inner," in order to enter into experience as an effective component. I am unable to see that any other meaning can be read into this view than that formulated in the current theory of psycho-physical parallelism. Causal connection between body and mind there is none; and the contrasts in our inner experience of them reside in apprehension, never in actual reality. The plain business of psychology, therefore, consists in applying observation, experiment and hypothesis to the "inner." Just as with science, regressive analysis supplies the methods.

Beneke concludes that psychological processes present themselves as complexes fashioned from four primary factors. These are: (1) The transmutation of sense "excitations"; (2) the formation of new "powers"—analogous, it may be said, to the growth of new tissue; (3) the redistribution of "excitations" (sensuous) and of these new "powers" or products themselves; (4) the interpenetratation of homogeneous products, according to their degree of homogeneity. Obviously enough, redistribution, or transference, within the psychological complex forms the dominant feature; and its forcible similarity to modern energistic conceptions or, as Professor Titchener remarks acutely, "to the process by which one body becomes cooler by communicating heat to another,"[20] needs no comment. Whatever one may think of Beneke's special doctrines, he stands to his material in the attitude of a positive scientific investigator. If Herbart worked like a mathematical physicist, Beneke works like a biologist. Indeed, he reminds one of the French school of so-called "organicists"—Bichat, Claude Bernard, Delage and, perhaps, Roux. I think a specious case could be framed for a parallelism between Beneke's teaching and Claude Bernard's biological conclusion, especially as formulated in the second Leçon in the first volume of his "Leçons sur les Phénomènes de la Vie" (1874), which contains the striking declaration: "la fixité du milieu intérieur est la condition de la vie libre indépendante."[21] Be this as it may, Beneke brought psychology within the purview of scientific inquiry. Like Herbart's, his conclusions might be stigmatized, but that both made preparatory contributions there can be no reasonable doubt. The *attitude* they adopted is of the essence of the matter. And one ought to add that the presence of unconscious or subconscious factors in the physical process, a highly significant phenomenon, follows from the situation as contemplated by them.

[19] "Lehrbuch d. Psychologie als Naturwissenschaft" (1845), Sect. 48.

[20] *Mind*, Vol. XIV., pp. 21–2 (old series).

[21] P. 113.

COINCIDENT ACTIVITIES OF THE EARTH AND THE SUN

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AMONG the inorganic factors by which the fitness of the earth for human occupation is most profoundly influenced, two of the chief are climate, on the one hand, and telluric activity on the other. To climate we owe much of the nature and depth of the soil upon which all life depends; it determines the character of vegetation, and makes possible the vast commerce which consists of the exchange of the vegetable products of one land for the commodities of another; it causes men to engage in different occupations, some, for instance, raising rice in the warm plain of Egypt, and others leading the life of the lumberman or trapper in the cold woods of Canada; and finally climate exerts a profound influence upon human temperament, the inhabitants of the torrid zone, as is generally recognized, being notably less energetic than those of temperate regions. Telluric activity, manifested in movements of the earth's crust, past and present, is equally important, though its effects are not so immediately visible. The ravages of earthquakes and volcanoes, great as they are, fade into insignificance when compared with the stupendous results which have followed from the upheaval of continents and folding of thick strata of solid rock. If telluric processes had not throughout the ages again and again upheaved the crust of the earth, the climatic forces of weathering and erosion would long ago have reduced the original continents to featureless plains of small extent compared with the present great areas of land. There would be no mountains full of minerals, and the use of metals would probably be unknown because none would have been discovered by reason of the enormous depth of soil which would cover the country.

In the study of climate and of telluric activity, attention has till recently been concentrated upon the earth. Within a few years, however, scientists have begun to turn to the sun to see if its changes are in any way connected with changes of climate or with the occurrence of earthquakes and volcanic eruptions. At first the results were negative. Of late, however, students of solar physics have shown that there are now in progress fluctuations of climate which appear to be coincident with variations in the activity of the sun as evinced by the occurrence of sunspots; and the investigations of Jensen, as I shall

presently show, seem to indicate an even closer coincidence between solar activity and the occurrence of earthquakes and volcanic eruptions.

Lockyer, Bigelow, Brückner, Clough and others have described climatic cycles averaging 3, 11, 36 and 300 years in length, all closely coincident with variations in solar activity. The 36-year cycle of Brückner is the best established and most easily recognizable. It is now accepted by the majority of meteorologists. It appears to pertain to the continental regions of the earth as a whole, although there are certain parts of the land close to the sea where the changes are the reverse of those in the interior. As to the seas data are not available. In continental regions the temperature is comparatively low at one extreme of the cycle; storms, clouds and precipitation are relatively abundant; storm-tracks of temperate regions approach the equator; snow lies long in winter; glaciers and rivers increase in size; lakes, especially those having no outlets, stand at a high level; and vegetation and animal life are appropriately influenced, as is evident from the time of the ripening of crops, and the expansion of irrigated areas in arid regions. These conditions prevail regularly at an interval of a few years after periods of exceptional activity in the sun. During the period of activity the 11-year sunspot cycle is reduced to 9 or 10 years, and there are other signs of unusual movement in the solar atmosphere. The other extreme of the Bruckner cycle follows a period of comparative inactivity in the sun, and is characterized by climatic phenomena the opposite of those just described. Meteorologists are not yet agreed as to the cause of the climatic cycles, but it seems to be well established that they are somehow connected with the sun.

In regard to the relation of solar activity to earthquakes and volcanoes, there is at present no agreement among students. On the whole, the evidence has seemed to most investigators to indicate that there is no relation. This appears to be largely due to the use of individual cases instead of averages, and to an attempt to find a coincidence between telluric activity, manifested in earthquakes and volcanoes, and *maximum* epochs of solar spottedness. Jensen, however, who has taken up the subject in a comprehensive fashion in volume thirty-six of the "Proceedings of the Royal Society of New South Wales," has come to a different conclusion. He has compiled a list of notable earthquakes and volcanic eruptions from 1783 to 1902. Each occurrence has been assigned a value of one, two, three or four, according to its severity, and all the earthquakes and eruptions for the whole series of years have been plotted as shown in Fig. 1. Having in this way obtained a graphic representation of the intensity of telluric activity in each year, Jensen added a curve showing the occurrence of sunspot maxima and minima. An inspection of the diagram thus obtained shows that

earthquakes and volcanic eruptions are most frequent and most intense during the years shortly before and after sunspot minima.

In order to estimate the reliability of Jensen's conclusion, it is necessary, first, to eliminate the personal equation by comparing his data with another set compiled independently; and, second, to eliminate accidental or sporadic occurrences and faulty observations by an appeal to averages. It has been possible to accomplish the first result by means of data which Mr. Robert W. Sayles, of Harvard University, has kindly put at my disposal. In the pursuit of certain researches having no immediate connection with the problem in hand, he had prepared a table showing the years of occurrence of notable earthquakes and eruptions from 1755 to 1902. He had divided the years into three classes according to the severity and number of the phenomena of both sorts in each year. He has kindly prepared the accompanying diagram (Fig. 1), showing, on the one hand, the years of telluric activity by means of the row of dots at the bottom, and, on the other, the number of sunspots by means of the wavy line. The open circles indicate years when notable earthquakes or eruptions occurred, although not in large numbers, nor of exceptional severity. They are reckoned as unity. The solid round dots represent years of greater severity than the preceding, and are reckoned as having a value of two in computation. The solid squares indicate extreme severity, and are reckoned at three. To the diagram as prepared by Sayles, I have added Jensen's data, as appears in the small rectangles above the sunspot curve. Jensen, unlike Sayles, has separated earthquakes and volcanic eruptions. Earthquakes are shown above the heavy horizontal line, and eruptions below. The size of the rectangles indicates Jensen's estimate of severity and frequency combined. For convenience of reference I have added the appropriate numerals.

The data of Sayles and Jensen supplement each other admirably. Neither investigator lays claim to absolute completeness in his data; but, on the contrary, both express regret that they have not been able to obtain fuller information. Nevertheless neither appears to have omitted any phenomenon of first-class importance. The method of compilation was quite different in the two cases. Sayles lays special stress upon the severity of individual earthquakes or eruptions; while Jensen emphasizes the total number of occurrences in a given year. The two sets of data were prepared without reference to each other; and different sources of information were evidently used, as appears from the relatively large importance which Jensen, an Australian, naturally assigns to the phenomena of Oceania. For instance, to illustrate the difference in the point of view, Jensen gives to 1835 the value of 6; while Sayles makes it one of the severest years, which on Jensen's

scale would give it a value of 20. Again Jensen reckons 1855 at 17, while Sayles put it in his lowest class which would give it a value of only 7. The next year, on the other hand, is reckoned by Jensen at only 4, and by Sayles at 14. Other years, such as 1873–4–5–6 and 22 others are given values of from 1 to 16 by Jensen, but are not mentioned by Sayles; while the latter gives an open circle to 1803, 1805, 1853, 1861, 1863 and 1885, although Jensen does not assign them a value of even one. Other discrepancies might be mentioned. They are natural, indeed unavoidable, in a subject where there is so much opportunity for the personal equation, as well as for diverse authorities. A man's estimate of the severity of an earthquake or eruption is sure to depend largely upon the vividness of the account which he happens to read. Hence the great value of having two independent sets of data compiled for different purposes by men living at the antipodes, New England and New South Wales. The discrepancy in the two sets of data is an advantage because the one supplements the other, and because where the original sources of information are so diverse, the harmonious result derived from averages is highly remarkable. It can not be the result of chance.

Inspection of Fig. 1 shows that according to both Sayles and Jensen periods of *minimum* sunspots are times of *maximum* seismic and volcanic activity; whereas at periods of maximum sunspots, telluric activity almost ceases. There are certain glaring exceptions, such as 1883, or 1906 which does not appear in Fig. 1; but it should be noted that in 1883 the sunspot maximum was only about two thirds as high as the average. In order to estimate the true importance of such exceptions, I have plotted the curves shown in Figs. 2–5, showing the relative frequency and intensity of telluric activity in years of sunspot minima as compared with other years. Figs. 2 and 3 show the frequency of years in which one or more notable earthquakes or eruptions—combined in the case of Sayles, separate in that of Jensen—have occurred at the sun-spot minima and during the intervening years. To illustrate concretely, it appears in Fig. 1 that out of fourteen years of minima included in the period covered by the investigations of Sayles, 11, or 79 per cent., have, according to him, been characterized by notable earthquakes or eruptions. Out of the thirteen years immediately preceding a minimum only 5, or 38 per cent., have had noteworthy seismo-volcanic phenomena; out of those preceding a minimum by two years, 6, or 46 per cent., and so on. Of course, the curve soon comes to zero at either end, because, on an average, five or six years before or after a minimum we come to a maximum separating one wave of the sunspot curve from another. To illustrate again, 1867 was a minimum year, and has a solid circle below the sun-spot curve and

two rectangles marked 2 and 6 above it. Therefore in calculating the data for the three curves of Figs. 2 and 3 it counts one in every case. So too does 1868, although it was a year of greater severity as is indicated by the solid square below the curve and the rectangles marked 12 and 8 above it. The year 1869, however, having only a single rectangle with a value of two, counts only in the computation of the data for the solid line of Fig. 3. 1870, on the other hand, is reckoned as one in computing the curve of Fig. 2 and the dotted line of Fig. 3. With 1870, which was a maximum year, we cease to count the years as being after the preceding minimum. 1871 is reckoned not as four years after 1867, but as seven years before the minimum of 1878, and so forth. By adding the figures for all the sunspot waves, and plotting the results, we get the simple frequency curves of Figs. 2 and 3. Figs. 4 and 5 are derived in the same way, except for one thing. Instead of reckoning each year of the occurrence of earthquakes or eruptions as having a value of only one, each is reckoned according to the value given it by Sayles or Jensen, respectively, as shown by the character or size of the spots and rectangles of Fig. 1. An inspection of the four curves of Figs. 2 to 5 shows that they agree in essential points. Each of the six curves, two for Sayles, and four for Jensen, has a pronounced maximum at or within a year of the time of sun-spot minimum. That is, when sunspots are fewest, earthquakes and volcanic eruptions are most numerous and most severe.

The four curves of Figs. 6 to 9 on the right-hand side of page — were drawn in exactly the same way as the four which lie beside them (Figs. 2–5), except that the sun-spot *maxima* were used as the reference points instead of the minima. They are introduced by way of contrast. It is evident that telluric activity is weak at times of sun-spot maxima. All the curves of Figs. 2 to 9 show the lack of symmetry characteristic of sun-spot variations. The lapse of time from maximum to minimum is greater than from minimum to maximum.

Having seen that there is a coincidence of some sort between sun-spot minima and seismo-volcanic maxima, the next step is to compare the mean sun-spot curve from maximum to maximum with the mean seismo-volcanic curve for the same period. The mean sun-spot curve is, of course, easy to obtain. Figs. 10 to 13 show the first stages in the construction of the mean seismo-volcanic curve. The time from one sun-spot maximum to the next is divided into eight periods as follows:

1. The year of maximum spots.
2. The year succeeding that of maximum spots.
3. An intermediate period of decreasing number of spots,—average length about 3½ years.

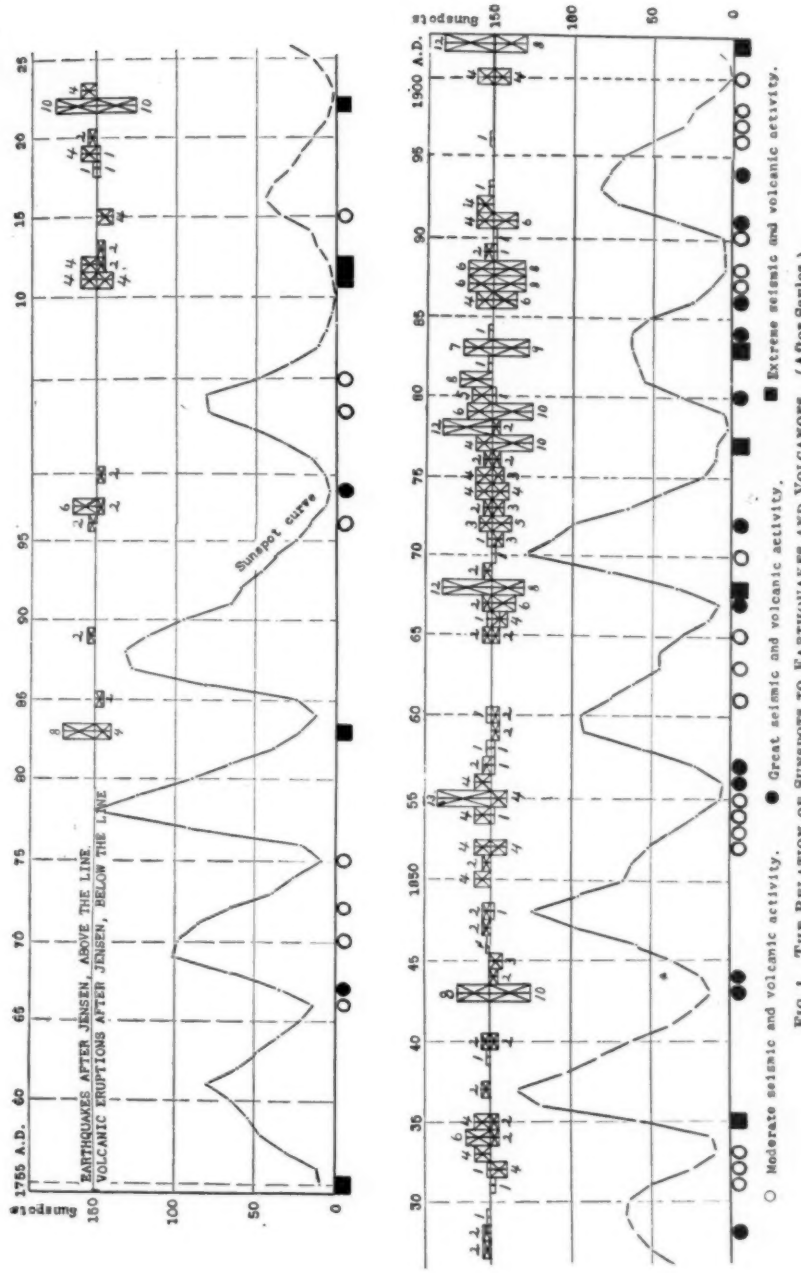

EARTHQUAKES AFTER JENSEN, ABOVE THE LINE
VOLCANIC ERUPTIONS AFTER JENSEN, BELOW THE LINE
Sunspot curve
Sunspots
1755 A.D.
1900 A.D.
○ Moderate seismic and volcanic activity. ● Great seismic and volcanic activity. ■ Extreme seismic and volcanic activity.

FIG. 1. THE RELATION OF SUNSPOTS TO EARTHQUAKES AND VOLCANOES. (After Sayles.)

4. The year preceding that of minimum spots.
5. The year of minimum spots.
6. The year succeeding that of minimum spots.
7. An intermediate period of increasing number of spots,—average length about 1½ years.

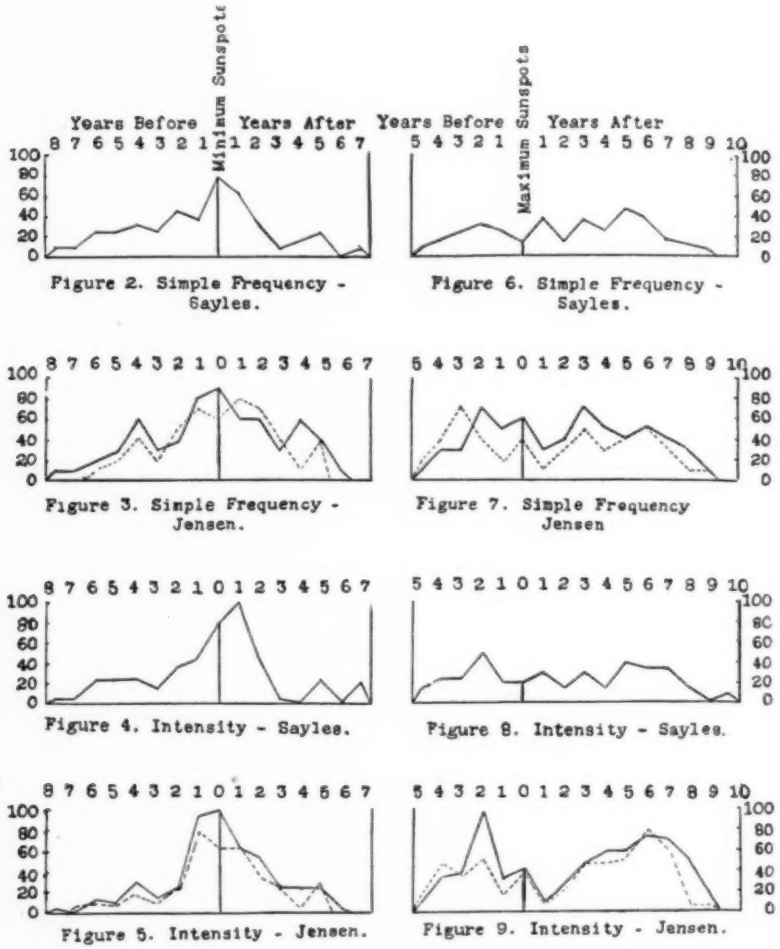


Figure 2. Simple Frequency - Sayles.

Figure 6. Simple Frequency - Sayles.

Figure 3. Simple Frequency - Jensen.

Figure 7. Simple Frequency Jensen

Figure 4. Intensity - Sayles.

Figure 8. Intensity - Sayles.

Figure 5. Intensity - Jensen.

Figure 9. Intensity - Jensen.

FIGS. 2-9. THE RELATIVE FREQUENCY AND INTENSITY OF SEISMIC AND VOLCANIC PHENOMENA AT PERIODS OF SUNSPOT MINIMA (2-5) AND MAXIMA (6-9). The numerals above the diagrams indicate years, those on the sides, percentages. In the diagrams compiled from Jensen's data the full lines indicate seismic phenomena, and the dotted lines volcanic phenomena.

8. The year preceding that of maximum spots.

The irregular periods numbered 3 and 7 are necessary because of the variation of the length of the sun-spot cycle. Number 3 may vary in length from 1 to 7 years, and number 7 from 0 to 3.

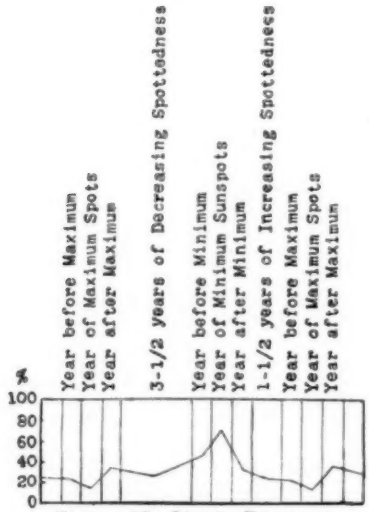


Figure 10. Simple Frequency - Sayles.

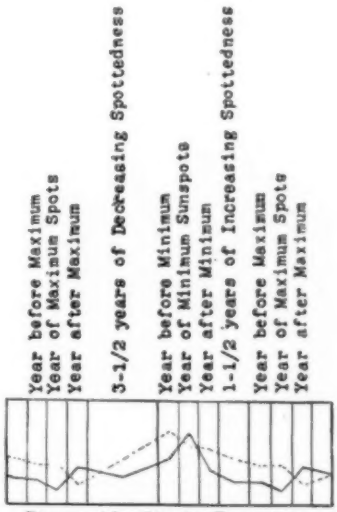


Figure 14. Simple Frequency.
____ Sayles' curve of Fig.10.
----- Mean of Jensen's two curves of Fig.11.

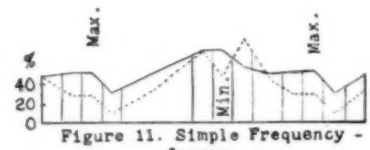


Figure 11. Simple Frequency - Jensen.
____ Earthquakes, ---- Volcanoes.

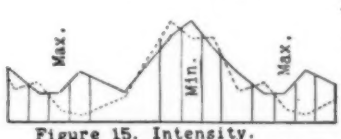


Figure 15. Intensity.
____ Sayles' curve of Fig.12.
---- Mean of Jensen's two curves of Fig. 13.

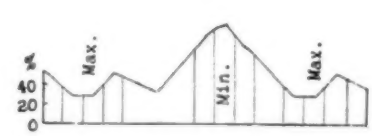


Figure 12. Intensity - Sayles.

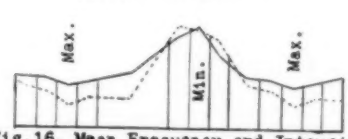


Fig.16. Mean Frequency and Intensity
____ Frequency, mean of Fig.14.
---- Intensity, mean of Fig.15.

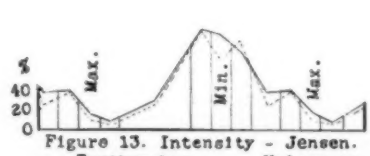


Figure 13. Intensity - Jensen.
____ Earthquakes, ---- Volcanoes.

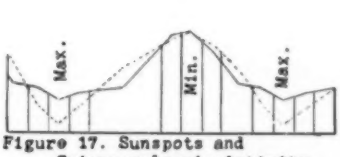


Figure 17. Sunspots and Seismo-volcanic Activity.
____ Seismo-volcanic curve, mean of Figure 16.
---- Mean Sunspot Curve since 1755, inverted.

For each of the eight periods of the sun-spot cycle, the percentage of years of seismic and volcanic activity has been calculated from the data of Fig. 1, as shown in the table at the end of this article, and has been plotted in the frequency curves of Figs. 10 and 11. For Sayles, 13 complete sunspot cycles are available, and for Jensen, 10. In the same way the average intensity of the phenomena of the years of each period has been calculated and plotted in Figs. 12 and 13. In order to obtain the mean curve it is necessary to combine the six shown in Figs. 10 to 13 into one. The first process is the combination of Jensen's four curves into two which shall be comparable to the two of Sayles. This is done in Figs. 14 and 15. In Fig. 14 the solid line reproduces Sayles's line of Fig. 10 directly, while the dotted line gives the mean between Jensen's two curves of Fig. 11. Thus we have two mean seismo-volcanic frequency curves. In the same way, in Fig. 15 the solid line reproduces Fig. 12, and the dotted line gives the mean of the two lines of Fig. 13; and we have two mean seismo-volcanic intensity curves. In these curves, as in the others, percentages are used, so that when diverse phenomena such as frequency and intensity come to be compared and averages computed, each receives the same weight. In Fig. 16 the frequency curves of Sayles and Jensen shown in Fig. 14 are combined into the solid line and the intensity curves of Fig. 15 into the dotted line. In order to make the two curves comparable the maximum in each case has been reckoned as a hundred. As a result of the combination of the data of our two authorities, the personal equation is largely eliminated. It will be noticed that the curves of Fig. 16 are much smoother than those of preceding figures. This is especially true of the frequency curve where there is least liability to errors of judgment. Finally, in Fig. 17 the two curves of Fig. 16 are combined into one, shown by the solid line. This represents the net result of Sayles's data as to the combined seismic and volcanic frequency and intensity of 13 complete sun-spot cycles, and of Jensen's independent data as to the uncombined seismic and volcanic frequency and intensity of 10 complete sun-spot cycles. The dotted line in Fig. 17 is the mean sun-spot curve derived from Fig. 1, and calculated and plotted in precisely the same manner as the six curves of Figs. 10 to 13 from which the mean seismo-volcanic curve is derived. For the sake of convenience in comparison, the sun-spot curve has been plotted with the minimum at the top.

The resemblance between the mean sun-spot and mean seismo-volcanic curves is extraordinary. The maximum of the one occurs at the same time as the minimum of the other, and in both cases there is a steady progress from maximum to minimum and back. If our terrestrial data of earthquakes and volcanoes were as complete as our

solar data of sun-spots, it is probable that the resemblance between the two curves would be still closer. It may be that the occurrence of earthquakes and eruptions lags somewhat behind the change in the number of sun-spots, but the lag is so slight that it does not appear where the unit of measurement is a year, although it might if the unit were a month. It seems to be impossible to avoid the conclusion that the marked coincidence between telluric and solar activity indicates a relation of some sort between the internal phenomena of the earth and the sun.

As to what that relation may be we have as yet no clue. The best that we can do is to speculate. It may be, perchance, that there is some cosmic source of energy as yet unknown, which pulsates through the universe causing both the earth and the sun to respond, each according to its kind. Possibly changes in the amount or in the nature of the energy emitted by the sun engender corresponding changes in the earth in some manner as yet beyond our ken.

At the present time, as we have seen, changes in the sun appear to be coincident with climatic and telluric changes in the earth. So far as we can judge, the climatic changes, though on a very small scale, seem to be of the same nature as the great climatic changes of the various glacial periods of earlier geological times. The telluric changes, also on a very small scale, are apparently of the same nature as the great movements of the past by which mountains have been formed and continents uplifted. It is notable that according to the general opinion of geologists the three best known and most severe climatic changes through which the earth has passed have been closely associated with profound modifications of the earth's crust. The glacial period which occurred just before the Cambrian period, far back near the beginning of legible geological records, was followed by a great change in the distribution of land and sea. Again after the prolonged period of comparative stability known as the Paleozoic era there ensued the severe Permian glaciation composed of many glacial epochs separated by warm epochs. At approximately the same time, or shortly afterward, there was a great uplifting of the continents and the formation of mountain ranges such as the Appalachians. Finally the last great glacial period, that of the Pleistocene and Pliocene was also a time of great mountain-building, when the Alps, the Sierra Nevadas, and the Himalayas received a marked uplift giving them their present altitude.

It thus appears that in geologic history the greatest known climatic changes have been closely associated with remarkable telluric changes. It appears that at present climatic and telluric changes on a small scale are coincident with or follow closely upon changes in the sun. The question at once arises whether there may not have been a similar

coincidence in the past. No attempt can be made to answer the question as yet, but it opens a most fascinating field of speculation and of investigation. If the activities of the earth and of the sun are related to one another in any such manner as is suggested above, the study of the one will add vastly to our knowledge of the other. An examination of solar changes, on the one hand, may enable us to foretell something of what is about to occur upon the earth. A careful reading of the geological history of the earth, on the other hand, may disclose the history of the sun for millions of years past, and may shed light upon the fascinating problem of the thermal history and ultimate destiny of the body which, as knowledge increases, appears more and more to be the arbiter of terrestrial life.

REFERENCE TABLE SHOWING THE DATA USED IN THE CONSTRUCTION OF FIGURES 2–17

Percentage of Years with Earthquakes or Volcanic Eruptions per Sayles	Percentage of Years with Earthquakes per Jensen	Percentage of Years with Volcanic Eruptions per Jensen	Average Seismic and Volcanic Intensity per Sayles	Average Seismic Intensity per Jensen	Average Volcanic Intensity per Jensen	Average Number of Sunspots	
15	50	30	0.31	0.70	0.40	99	(1) Year of maximum sunspots.
38	30	10	0.54	0.40	0.33	83	(2) Year after maximum.
28	51	36	0.33	1.30	0.95	44	(3) Three and one half years of decreasing spottedness.
46	73	73	0.92	4.17	4.10	15	(4) Year before minimum.
71	73	45	1.07	4.00	2.73	7	(5) Year of minimum sunspots.
36	55	82	0.82	3.27	3.55	19	(6) Year after minimum.
24	47	42	0.52	1.58	0.89	40	(7) One and one half years of increasing spottedness.
23	50	30	0.31	1.70	1.50	79	(8) Year before maximum.

SPRINGS AS A GEOGRAPHIC INFLUENCE IN HUMID CLIMATES

By Professor FRANK CARNEY
DENISON UNIVERSITY

IN the arid southwest parts of the United States, the crude water signs of the Indians have often pointed the white man to a spring. The government topographic maps covering sections of this region of sparse rainfall give the location of many springs. Throughout the longer-known and more-traveled desert areas of the world, the few oases have fixed the routes taken by caravans. Numerous books are available detailing facts that bear on the geographic influence of springs

A Reconnaissance Contour Map in which the altitudes were ascertained by working aneroids in pairs, a method explained in the *Journal of Geology*, Vol. XV. (1907), p. 492. In this area there are 203 dwellings, 148 of which are located at springs.

A PRIMITIVE LOG HOUSE nestled among the trees marks the location of a constant spring.

in arid climates. But into whatever land man has gone, humid as well as arid, springs have had a part in his activities. So far as America is concerned, I am not aware that a quantitative study of the influence of springs in humid regions has been undertaken.

While mapping the stratigraphy of an area of approximately 25 square miles in central Ohio, where the annual precipitation is about 40 inches, the influence exercised by springs was given particular attention. In this area the upper formations of the Mississippian, and the lower of the Pennsylvanian periods come to the surface. The vertical series of rocks involves two horizons of coarse clastic sediments, the Black Hand of the earlier period, and the Sharon member of the Pottsville, which is the lowest formation of the later period. The Black Hand overlies the Cuyahoga, which in central Ohio "is composed largely of bluish and grayish shales and buff sandstones."[1] Subjacent to the Sharon is the Logan formation consisting chiefly of "buff arenaceous shales to thin bedded sandstones."[2] The Black Hand is a massive sandstone, locally conglomeritic; the Sharon is less massive, and locally coarser; this characterization of these two formations applies specifically to the area studied. While neither of these sandstone formations overlies impervious beds, yet in themselves they are variable in texture and structure, and the region is so maturely dissected, that conditions are very favorable to the development of springs. Furthermore, the Logan also contains beds that are water-bearing.

The early settler in agricultural lands found a spring, if possible,

[1] Charles S. Prosser, *Journal of Geology*, Vol. IX. (1901), p. 220.
[2] *Ibid.*, p. 231.

and then built his log house. Others coming into the region made similar locations. Settlement generally moved along streams, since in the absence of roads valleys are more accessible. If the valley has been developed in water-bearing formations, which are not much tilted, springs border the bottom land on either side. Both topographic convenience and the presence of water tended to confine the earliest habitations to the valleys. Later settlers spread over the intervalley areas, building their houses in proximity to springs.

Primarily the highways lead from house to house; eventually, however, several factors become operative before the roads are permanently fixed. In the case of a valley having a commodious floodplain, but not extensive enough to warrant the maintenance of roads on each side, the slope bearing the better springs was normally the decisive factor; the homes on the opposite side would be approached by fords and lanes, or by only the latter if located near a transverse highway. In the uplands the permanent lines of traffic appear to take courses that will accommodate the greatest number without making too great sacrifice in distance; even then some dwellings are isolated. The isolation may continue but one generation, or until the desire to live on the highway overcomes the convenience of water and the associations of the hearth; the latter factors have prevailed wherever we see an isolated frame house, whereas a deserted log cabin means the dominancy of the former.

Moreover, the intervalley highways sometimes exhibit an economic influence. When the area is heavily timbered, and lumbering rather than agriculture is the initial occupation, the roads made in connection with logging and milling may become permanent. For example: North of Wilkins Corners (see map) the second highway leading west ascends about 160 feet in one half mile; this road parallels a valley a

THE IRON CONTENT OF THIS SHARON ROCK induces the "honeycomb" effects in weathering, and also makes the springs less desirable.

THE GENTLE SLOPES OF THE LOGAN FORMATION AFFORD GOOD FARMS, but few springs for dwellings. Twice as many houses are found along the lower contours of the Black Hand formation where water is plentiful.

few rods to the left, where the same horizontal distance involves only half the grade; the original highway did follow the valley, connecting the two houses. But log-haulers from the wooded upland located their main road where it would command as much of the area as possible, approaching it by spurs along contours. This traffic fixed the road where it is, though it has never led directly to a dwelling; property complications diverted the second house up the valley to it, the original roadway being abandoned. A similar influence in highway-location due to mining operations is seen one and one half miles west of Mary Ann Furnace in the road trending southwest from the one leading to Wilkins Corners. Some fifty years ago a vein of coal on this slope was worked for local use, and was approached from the west, thus opening a highway that has served little use since.

It is evident also that so far as the intervalley roads are concerned, the topographic factor made slight appeal to the locating engineers, an ox-team and its driver. If the most direct line between houses, *i. e.*, between springs, crossed a sharp hill, the highway went directly over rather than follow a contour, or take even a gentler, if slightly longer, grade. I have noted several places where in the past decade these sharp grades have been removed by a detour, but two generations had dragged themselves wearily over the hill.

The convenience of good water, or of rich bottom lands in the valleys, factors that would seem to have much weight with the early settler in choosing a location, is of secondary importance when opposed to an inherited topographic proclivity. A man reared among hills, however barren, has a latent tendency to plant his new home in similar topography. This bias, developed through environment, whether inherited or acquired by the individual, is illustrated in the choice of lands made by Welsh immigrants who came into Licking County, Ohio, early last century; they passed by thousands of acres of lowlands, the richest in the state, and selected farms in a rugged portion of the county, still owned by their descendants, and even now designated "The Welsh Hills."

But in the region to which special study was given, the geographic influence of springs is obvious. There are 203 houses in the township, 148 of which are built at springs; some of the fifty-five using wells formerly depended on springs. Both the horizontal and vertical distribution of these dwellings is largely a matter of stratigraphy of which the springs are a manifestation. It should be noted, however, that the localization of houses near Mary Ann Furnace is due to the fact that over sixty years ago iron ore, found in the neighboring hills, was reduced here; stoves also were manufactured at this place. The furnace was destroyed in 1853, but the houses are still in use.

Over fifty per cent. of the dwellings with springs are in the horizon

THE TINY RILL OF A SPRING THAT HAS ALREADY DEVELOPED A SMALL BASIN.

of the Black Hand formation, which borders the floodplains of all the valleys, a distribution made possible because the formation has an eastern dip of about twenty-five feet per mile. The springs in the Black Hand are numerous and copious, partly because of the thickness

THE BLACK HAND FORMATION is generally a coarse, irregularly bedded sandstone, yielding a copious supply of spring water.

and texture of the formation, also because of its subjacency to horizons that carry water freely.

In the Logan formation, I have mapped thirty houses with springs. There is doubt concerning a few of these, an indefiniteness occasioned by the absence of contacts. The Logan sediments suffered erosion contemporaneously with Pottsville sedimentation; furthermore, the Logan, in comparison with its contact formations, the Black Hand and the Sharon, weathers easily, producing gentle slopes. These two conditions make it doubtful about the exact horizon of a spring near either the top or the base of the Logan.

SAWED SHINGLES AND A FEW BOARDS ARE USED IN LENGTHENING THE YEARS OF SERVICE OF THIS ROUGH-HEWN LOG SPRING HOUSE.

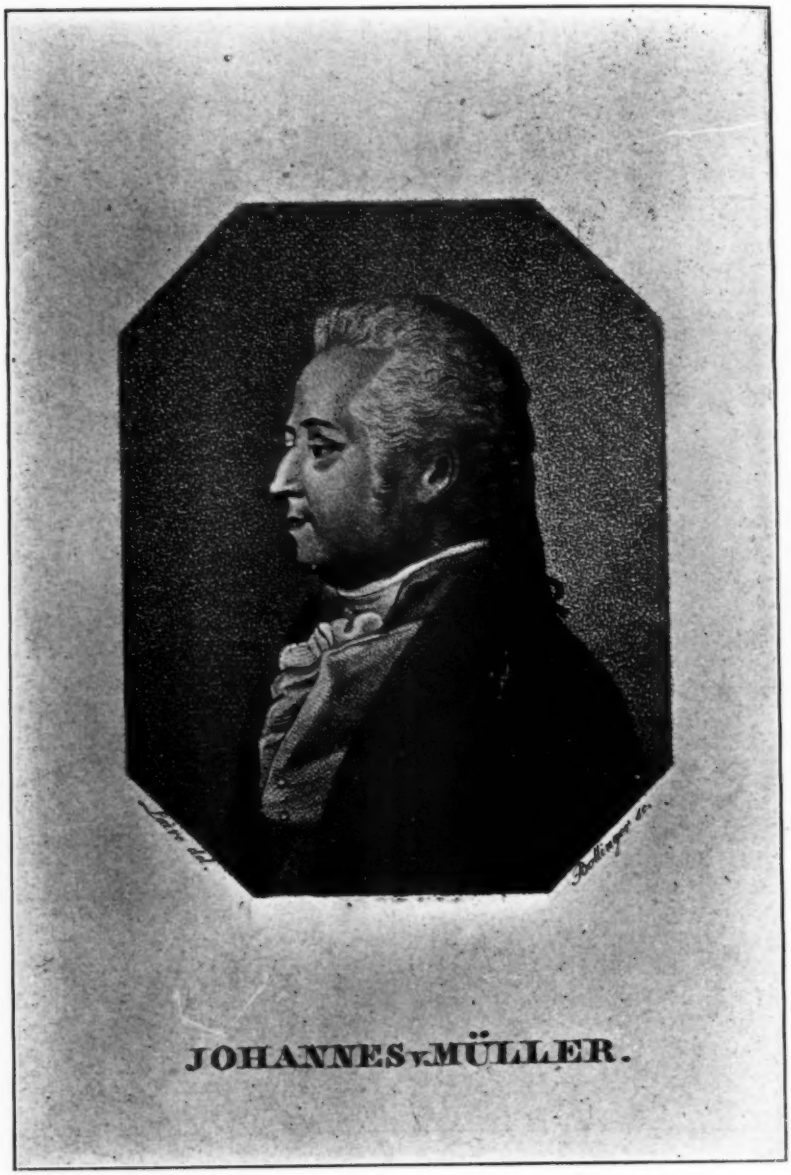
Slightly less than seventeen per cent. of the houses with springs are found in the Sharon. The areal extent of all the exposed formations diminishes vertically, hence the number and the volume of the springs decrease; the value of the land for farming also decreases with altitude. A further fact concerning the springs of the Sharon is their content of iron, making them less desirable than springs in either of the lower formations.

A Mature Stage of Erosion is a Condition favorable to Numerous Springs.

The township contains no extensive areas of outcropping coal measure or Pennsylvanian formations, save in the south central portion; elsewhere disintegration has left only outliers. In the area west of Mary Ann Furnace, covering several square miles, and another along the eastern border of the township, there are eighteen houses, three of which, now occupied, have springs. For the entire township, the average number of houses per square mile is about eight; for the horizon of the coal measures, it is less than two. That springs are rare is not the sole cause for the discrepancy; the bleakness of the upland, and the unproductiveness of the soil are contributory factors.

About ten per cent. of the homes with springs are built on glacial deposits. The drift is localized chiefly in the valleys. The ice-sheet covered approximately two fifths of the township, but left scarcely a veneer of drift on the intervalley areas. While fourteen springs have been mapped as belonging to the drift, it is quite probable that a good fraction of these are fed by water courses from the Black Hand formation. Of the wells noted, fifty-six per cent. are in glacial deposits.

Still another evidence of the influence due to springs is seen in the fact that of the eight deserted houses in the township one is in the Black Hand formation, one in the Logan and six in the coal measures, the horizon practically without springs. It is noted also that twenty-two per cent. of the dwellings are off highways, an isolation due entirely to springs. Furthermore, dairying has always been carried on in this region because in the summer season the springs furnish cool water for handling milk.



JOHANNES v. MÜLLER.

JOHANNES MÜLLER[1]

By Dr. PHILIP B. HADLEY
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IN the present day when the individual laborer in the fields of biology is so often lost in the flood of new facts which is continually being poured into the archives of the science; when a narrow specialization and very definite concentration of activity are the primary condition and means for furthering the highest interests of the science as a whole, and when the difficulty is ever increasing, to hold in the foreground the larger and more general problems of biological significance, it may not be altogether inappropriate to recall—we might almost say revive—at times, some of the monumental figures whom the history of every science, at rare periods, brings forth, and to learn once again our debt to them.

That the times are past when it is permitted a single individual to survey, in full understanding, the broad fields of activity in the realm of general biology must assuredly be considered as a sign of advance. We may even remark that the gradual expansion which physiology alone has undergone during the last half century, in passing beyond the confines of a unitary science and in trespassing—perhaps with right—upon the fields which had at one time belonged to other realms, is a necessary consequent to the death of the last great ruler of the science. For these reasons alone it may be of interest and of profit to recall the single instance of a man who, during his years of activity, so deeply influenced the drift of physiological thought; and after whose death, the overgrown and no longer self-containing science of physiology burst like a great stream at its mouth, by many and devious channels to reach the sea.

Johannes Müller was born in the city of Coblenz on the fourteenth day of July, 1801, the son of Mathias Müller, a shoemaker. Although a man of small means, the father determined not to deny his son the advantages of a fair education, and accordingly the young lad was sent to the Jesuit school in the place of his birth, then under French control. Here he remained for eight years, pursuing a study of the classics and mathematics and gaining the foundation of that knowledge of Greek used so brilliantly in after years in the translation and

[1] On the above subject the writer would acknowledge the especial value of two German works from which he has freely borrowed: A comprehensive treatise by DuBois Reymond, "Gedächtnissrede auf Johannes Müller"; and a brief paper by Max Müller, in *Westermann's Monatshefte* for July, 1901. The present paper was first presented in a course of biological seminars at Brown University.

commentation of Aristotle. A few years later we find him at the Gymnasium, where, in spite of the old scholastic system of teaching, he took a deep interest in the study of the animal and plant worlds—an interest which was no doubt stimulated by the reading of Goethe, whose works were a source of great delight to young Müller. During this period there also appears to have developed in him that rich gift of imagination which, as one of his biographers says, is so necessary not only to the poet, but also to the natural investigator. In his later work on the "Phantasmal Phenomena of Vision," Müller tells us how, as a boy, he perceived in the crumbling walls of a neighbor's house all sorts of odd and fantastic figures and faces.

At the age of seventeen, Müller left the Gymnasium and, having served one year in the army—as was customary with the youths of his station—he entered, at the age of eighteen, the University of Bonn, which had just been founded. As has been the case with so many natural scientists, here Müller at first hesitated in making his decision between the church and medicine. Born as he was of Roman Catholic parents and nurtured in the Catholic faith by a strongly believing mother, it is not strange that, even as a child, he manifested a desire to enter the priesthood. But the decision was soon made. For three days, so we are told, young Müller closeted himself in his room in order that he might deliberate. At the expiration of this time he made known his decision to a friend in these words: "I am determined. I shall study medicine; for I know what I have and whom I serve."

While at the University of Bonn, Müller's career was characterized by an intense application to study. He maintained, however, a constant exercise of independent thought, and manifested a keen relish for original investigation. Here he initiated, even in the first year of his studies, a series of experiments upon the "respiration of the fœtus," a subject in which a prize had been offered by the university. This prize Müller secured when at the age of nineteen. In connection with the work, a story which a friend of Müller has made known, is characteristic of the young investigator at this time. He had once started upon a journey on horse to Arrthal and was but a short distance on the way when, by the roadside, he espied a pregnant cat. He immediately gave chase, captured it and, for the time being postponing his journey, carried the animal back to the university, where, by Caesarian section, he deprived it of its young in order that he might consequently solve some point in his first problem of investigation.

During the early part of his period at Bonn, although as a student he was most intent upon his work, he was not wholly indifferent to the general yearning for constitutional freedom which was pervading the thought of the middle and lower classes throughout the German

states after the expulsion of the French. The movement towards a student alliance was then at its height, and this seized strongly upon Müller, who, as we learn, took a leading part in that rather enthusiastic association in which the academic students still cherished hopes of a German unity.

Even these early investigations of Müller were bringing him to the notice of many of the scientific men of his time. On the occasion of the publication of his work on the "Laws of Animal Motion," Oken, the then famous natural scientist, expressed his high approval together with the wish that Müller might be permitted to devote himself purely to natural science. Of this course of action, however, there seemed at that time little prospect. After the death of Müller's father, the small family inheritance lasted but a short while; and from this time until the dawn of his European fame Müller appears to have been constantly troubled with the distressing problem of obtaining the necessary funds for the continuance of his labors; and often even with the question of obtaining food. But in spite of the difficulties which his financial condition enforced upon him, this was on the whole a gay time. The thoughts of the wide possibilities of his chosen vocation appear to have maintained the spirit of the youth, and the unquenchable thirst for knowledge and recognition was gratified at every spring which philosophy, literature, theoretical natural science and careful observation offered. It was also here and during these early years of his study that Müller contracted the spirit of the *Naturphilosophie,* from whose grasp he was freed at a later date through his contact with Rudolphi at Berlin.

When we consider the trying conditions which surrounded Müller in this period of his life, it must be considered most fortunate that there stood at the head of the Prussian ministry a man who, more than any other, appears not only to have recognized Müller's genius, but also to have had the ability to loosen the fetters which bound up Müller's great gifts. This man was the Minister von Altenstein; and it was he who, by securing a generous government stipend, made it possible for Müller to spend two years—from the spring of 1823 to the autumn of 1824—in furthering his scientific studies at Berlin, where Müller shortly passed his examination for the license to practise his profession of medicine.

It was here that Müller had the great good fortune to become the favorite pupil of Rudolphi, who at that time was the most formidable enemy to subjective speculation in biological science, and who already had begun to base physiology—rather exclusively, perhaps—on the actual study of animal structure. It was Rudolphi, moreover, who had the liberality to place at Müller's disposal his laboratory, his apparatus, his library, and what was still more advantageous, his constant oversight and advice. Of the encouraging aid which he received

from that excellent master, Müller afterward spoke in the most grateful terms, and declared that it was through the influence and example of Rudolphi alone that his own scientific pursuits were afterwards turned so fully in the direction of comparative anatomy.

At the expiration of his two years of labor, and immensely enriched in all the fields of natural science, Müller again returned to Bonn, and in 1824 was enrolled as academic lecturer in comparative anatomy and physiology. Two years later, when but twenty-five years old, he was made professor extraordinary in the same branch of science.

The epochs in his activity in investigation which immediately followed upon his return to Bonn have well been called by DuBois Reymond the *subjective physiologico-philosophical period.* The literary landmarks of this period in Müller's career are two works: First, "On the comparative physiology of the sense of sight in men and animals, with researches on the motions of the eyes and on the sight of man"; second, "Concerning the phantasmal phenomena of vision: a physiological research dealing with the physiological evidence of Aristotle concerning dreams, the philosophies and the arts."

In the former of these two works we find recorded that excellent discovery that the sight of insects (which possess facet-eyes) must be conceived of as a mosaic interpretation of objects; that is, the pictures which the insects themselves see are placed together as in the form of a mosaic. In the second work regarding the "Phantasmal Phenomena of Vision," Müller took up a study, the idea of which reached far back into his earliest youth, when he was accustomed to give free play to his fancy in imagining strange shapes and figures on the plaster-scarred walls of the old buildings. These fanciful appearances, which thus early became so familiar in the imaginings of his boyhood, he submitted in maturer years to searching philosophic scrutiny; and the work in which they are described and discussed is a charming yet masterly application of experiment in anatomy, physiology, physics and psychology. Through the medium of these scientific principles Müller explained the seeing of devils and spirits; the friar, who, after long hours of supplication, sees the desired consecration in the form of a shining cloud; the superstitious, to whom the tempter appears as an evil spirit: these phenomena were for Müller only the results of the passion-aroused conditions in the material substances of their sight.

Of all Müller's labors at this time, greatest importance must be attached to his work in elucidation of the laws of the specific energy of the sense organs. With ingenious experiment he worked out the general law that, in whatever manner a sense organ may be stimulated, it always answers to our consciousness by the method peculiar to it. It was from these and other related investigations that Müller deduced many of his philosophical principles: For instance, that we can not

understand truly the things of the world outside of ourselves, but are cognizant only of the changes brought about in the sense-substance by the thing itself. From these considerations we can readily understand how Müller was led to adopt the view of subjective idealism.

During this period at Bonn, however, the duties which, as a teacher, Müller imposed upon himself, together with the unremitting employment in the lines of his original investigations with all its concomitant labor and thought, had induced, soon after his marriage in 1827, a state of mental and physical exhaustion. Upon the eve of a nervous break-down he secured a leave of absence from the university and with this a recompense of two hundred thalers which made possible for him a journey up the Rhine and through southern Germany. On this trip he was accompanied by his newly married wife. Soon, however, with bettered health he returned to Bonn, where in 1830 he was made professor ordinary.

This event marks the end of what we may term Müller's fiery subjective period, and the beginning of his great *objective physiologico-anatomical period,* which covered the years of his most brilliant achievement. He was now devoting himself to many branches of scientific work, especially to his morphological studies. Through his anatomical and systematic researches on the scorpion and spiders, he showed himself worthy to be ranked among the first zoologists of his time. In his work, "On the Development of the Reproductive Organs," which appeared a few years later, Müller traced the development of these organs in man and in animals. Coincident with this he was pursuing his researches into the development of other organs, and produced his treatise on the secreting glands. In this excellent work the phylogenetic and ontogenetic development is considered in both man and the lower animals.

In the latter part of Müller's life at Bonn occurred two significant physiological discoveries: First, he definitely proved, through a convincing series of experiments on the frog, the view which had been first announced by the Englishman, Charles Bell, in 1811: that the anterior roots of the spinal cord are motor, and that the posterior roots are sensory in function. In reality this experiment was simple enough. In a frog Müller cut on one side the anterior and on the other the posterior nerve roots of the spinal cord. On the side on which the posterior roots were cut the frog was wholly insensible, while the side on which the anterior roots were cut remained quite paralyzed. This experiment awakened in the scientific world of that time a storm of applause. The fortunate experimenter journeyed to Paris in order to demonstrate the fact before Alexander von Humboldt and Cuvier. Versalius in Stockholm had the experiment performed by Retziüs. Hardly a year later, Müller announced his discovery of

the lymph hearts in amphibia; and also the results of his investigations on the coagulation of the blood.

Just and prompt recognition did not fail to follow in the train of these excellent results, and the consequent advancement and improvement in his material condition made possible for him other interesting journeys. In 1828 he visited Goethe. The spring of 1831 he spent in the Leiden Museum in Holland. In the autumn of 1831 we find him in Paris in the company of several of the great natural scientists, as Humboldt, Cuvier, Milne Edwards and others who were there at the time. One significant anecdote of this Paris trip should not be omitted. When for the first time Müller went to call upon Dumereil, the latter was very busy, and, since he did not know whom he had to meet, somewhat peevishly directed Müller to the door. Müller, however, as he was almost thrust out, pushed in his head and called out to Dumereil, "Yes, but the Coecilien in the young stages *do* have gill openings in their necks!" This thrust, it is needless to say, worked as a magic word to gain a long and pleasant interview between these two investigators.

In the year 1832 Rudolphi died at Berlin, thus leaving vacant the foremost position in anatomy and physiology in Germany. Negotiations were already in progress to secure as Rudolphi's successor Dr. Tiedermann from Heidelberg; but at this point in the proceedings Müller determined upon a unique step. He sent to his old friend and former benefactor, the Minister von Altenstein, copies of his works together with a letter in which he ("believing that the importance of the affair would furnish its own excuses") brought himself prominently into the proposition. He said, in part, that it was no more than right that the first and highest position of the kind in Germany should belong to the greatest among scholars; furthermore, that if this man were not Johann Friedrick Meckel, then he believed himself to be the foremost zoologist and physiologist in Germany.

This letter had results: the Minister von Altenstein at once ordered Müller's nomination; and on Easter, 1833, Müller, not yet thirty-three years old, entered upon his duties as "professor ordinary of anatomy, physiology and pathological anatomy, and director of the Anatomical Museums" in the University of Berlin.

The first fruit of Müller's residence in Berlin was the completion of his "Handbook of Physiology," which he had begun long before he left Bonn. Appearing in three parts, it was at last completed in 1840. These volumes represented a piece of work unparalleled in the field of physiological literature. The only work which could be compared with it was Haller's "Elementa." Müller's labors in preparation for this work included an immeasurable number of single observations with reference to the physiology of the voice, of speech, of hearing, of nerve physiology, of teachings on the blood—all of these rest,

to a very great extent, upon Müller's own discoveries. The "Handbook of Physiology" was accepted with almost universal accord as the most valuable treatise on general physiology that had appeared in the long interval since the time of Haller. It is perhaps of interest to observe that these two writers have much in common, for in both we perceive the fundamental desire of placing the doctrine of physiology upon a basis of fact. Anatomy, human and comparative, experiments on animals, chemistry and physiological science in its various departments, are all called in to bear upon the investigation of the truths of physiology. As one of his commentators has remarked, Müller in this work, as in his others, takes nothing on trust; every statement, whether matter of fact or of doctrine, is thoroughly tested; difficulties, however perplexing, are never evaded or slurred over; defects, however much they may deface the picture to be presented, are never disguised. The result of each quest, whether success or failure, is honestly told and there is no yielding to the temptation, so powerful with writers of systems, "to round off a ragged subject with smooth plausibilities." The influence of the "Handbook" was immense, and the judgment of it appears to have been conditioned not alone by the physiological data it contained, but also by the collected facts of importance to the medical profession.

With the completion of the "Handbook," Müller's activity in this particular line of work seems to have practically ended. From this time on he engaged himself to a greater extent in the fields of comparative anatomy and zoology; and in these subjects, as also in his physiology, Müller excelled both in the abundance of his observations and in the wide range of his discoveries. In his work on the comparative anatomy of the myxinoid fishes, Müller lays down the morphological plan of the vertebrates in their simplest form. The title conveys but a faint notion of the scope of this work. Although it treats chiefly of the anatomy of this particular family of fishes, it is rich in new and original matter in which the structure is compared with that of other families of fishes, and the facts sagaciously applied to the elucidation of greater questions in animal morphology. Regarding Müller's study of the Echinoderms, we may quote from an address by the president of the Royal Society of London:

> Professor Müller early applied himself to the study of the structure and economy of the Echinoderms. After describing in a special memoir the anatomy of Pentacrinus, so interesting as a living representative of the extinct Crinoidea, and publishing, in conjunction with M. Troschel, a systematic arrangement and description of the Asteridea, he was at length happily led to investigate the embryo life of this remarkable class of animals. The field of inquiry upon which he entered had scarcely been trenched upon before, and he has since made it almost wholly his own by persevering researches carried on at the proper seasons of the last nine years, on the shores of the North Sea, Mediterranean and Adriatic. In this way he investigated the larval conditions of four out of the five orders of true Echinoderms, and has successfully sought out and determined the commonplace followed in their development, amidst

remarkable and unlooked-for deviations in the larval organization and habits of genera even of the same order. His inquiries respecting these animals have made us acquainted with the larval forms, with relations between the larva and future being; and with modes of existence, such as nature has not yet been found to present in any other part of the animal kingdom. Finally with the light thus derived from the study of their development, Professor Müller has subjected the organization of the entire class of Echinoderms, both recent and fossil, to a thorough revision, and has added much that was new, as well as cleared up much that was obscure in regard to their economy, structure and homologies. It is to their researches, which occupy seven memoirs of the Royal Academy of Sciences of Berlin, that more special reference is made in the award of the medal.

It was not long after his arrival at Berlin that Müller established the *Archiv für Anatomie und Physiologie.* Of this he continued the publication until the time of his death. This journal, during the period of its existence, formed a principal medium of publicity for the labors of the leading physiologists of Germany; and the establishment and continued superintendence of it by Müller, in the midst of other laborious employments, must be regarded as an important service rendered to science.

About this time, independent of Müller, his pupil Schwann, following apparently in the footsteps of Schleiden, made the discovery that the animal organism, just as the plant organism, was composed of elementary cells. Müller appears to have been the first to recognize the great significance of this discovery. He immediately employed the new fact for the explanation of certain disease phenomena and clearly pointed out the agreement between tumors and pathological and embryological development. His excellent work on the finer structure of morbid tumors signifies the beginning of all microscopical investigation in pathological anatomy, and here we see the fountain-head of that stimulus which, brought to bear upon the young investigator Virchow, gave rise to that well-known and comprehensive work on "Cellular Pathology."

Concerning the other events of Müller's life, during the Berlin period, it takes little time to relate. The routine work in the Berlin Anatomical Museum was interrupted only by the scientific expeditions which the desired investigation of the sea fauna afforded. The East and North Sea, Sweden, Norway, the coast of the Adriatic and Mediterranean, from Triest to Messina and Marseilles, formed the territory of Müller's scientific explorations. On one of these trips, in 1855, Müller experienced a serious danger. He was returning with two pupils from a journey to the coast of Norway, when at night the steamer *Norge* on which he sailed was rammed by another and speedily sank. Nearly fifty people lost their lives; and among them one of Müller's young companions. In a letter to a friend in England, in which Müller gives an account of the disaster, he says that upon finding himself in the water at first he kept himself up by swimming. But having his clothes on, he soon became exhausted and would have

perished had he not caught hold of a ship's ladder which was floating by. For a long time he held on, and had nearly given up all hope of assistance when he was picked up by a boat from the other vessel. His remaining companion, Dr. Schneider, saved himself in a similar way. This event seems to have had a deep effect upon Müller, and although he still resorted to the seaside, ever afterwards he dreaded to trust himself on shipboard.

When, for a second time, Müller was chosen director of the Berlin Museum, it was certainly most unfortunate that his directorship fell in that memorable year of the revolution, 1848. Although Müller felt himself to be truly German, he was apparently no more of a politician than Goethe. He could experience no sympathy for the democratic rashness which on all sides of him was now being manifested. It was a time of civil commotion when political agitation distracted the whole academic being, and both students and professors were deserting the laboratory and lecture room to equip themselves as soldiers of the revolution. Müller, whose quick spirit had led him, in the olden days of the Student Alliance, to take so active a part in the threatened political eruption, had become a sober conservative. His situation was now one of difficulty, and not without peril. He strove manfully to maintain authority, and even those who took a different view of passing events paid willing tribute to his honesty of purpose and to the personal courage he displayed in the most trying circumstances when the university buildings had become the center of the intense revolutionary movement. Müller naturally feared the destruction of the priceless treasures of his collection. Regarding the state of his mind we can obtain some conception from the words of his distinguished scholar, Rudolph Virchow, who upon Müller's own request became his follower as professor of anatomy and physiology at Berlin University. Regarding these days of the revolution, Virchow has written as follows:

> He trembled for the safety of the university, for whose treasures he felt himself to be personally responsible. Day and night he remained at the museum, ever on guard. He tore down agitating placards. He ventured with personal danger among the students. On the day of the great citizens' parade, with his own hand he seized away the black banner which was stretched across the balcony of the university building. But the movement more and more escaped the authority of the academic jurisdiction. In the teaching body of the university grew the voicing of disharmony. The professors and the private lecturers made diligent efforts to be heard and some of them (appointed as a committee, to which I also belonged) argued the matter with the director and the senate in a very unpleasant conversation.

Thus it is apparent that Müller was asked in the most kindly spirit to give up, at least temporarily, the position as director; for Virchow continues:

> Thus all agreed, in order to relieve the at least exposed position of the director, to a painful duty; and it was an actual deliverance when, at the closing of the university year, he could give into other hands the office which he had taken upon himself.

This was, perhaps, the most unfortunate directorship since the

founding of the university; for the man who possessed the least political inclination was called upon to display, in that time of agitation, the abilities of the politician and statesman.

From this time on Müller worked as hard as ever, but with sadly altered spirits. The nervous strain of overwork was beginning to tell. He suffered much from sleeplessness and this condition he fought with larger doses of opium, which in turn led to a more serious trouble of the heart. In the winter of 1856–7 his health received the first open shock when a gastric fever, the first serious illness since 1827, necessitated the giving up of his lectures. In these days he worried much about himself, feared typhoid fever and wrote to his son, Max Müller, at Cologne. He set in order all his private affairs and engaged, in the case of his death, Dr. Diffenbach to open his body. At this time, however, he developed only a slight trouble in the joint of one foot, and the next summer found him again in fair health. The following winter, however, he again overburdened himself with work, suffered even more than ever from lack of sleep, and again resorted to large doses of alkaloids. For some time he had suffered from moments of dizziness, but had become accustomed to attribute them to the long hours he spent bending over his microscope. These attacks now became so frequent that he dared not venture even on his library ladder. In the evening one would see him sitting listless in his easy chair; or, as if driven by a deep inner anxiety, and gloomy foreboding, pacing restlessly at night through the secluded streets of Berlin.

Easter of the year 1858 did not bring him the accustomed feeling of satisfaction at having completed a period of uninterrupted scientific work. At the end of the summer semester he fully realized, but all too late, the necessity of taking the most energetic measures to bring about an improvement in the condition of his health. He again called his son from Cologne, and, after a consultation, decided to give up all his work and lectures in physiology. He planned an early consultation with his physician in order to decide more definitely regarding his future work; but the end came suddenly. On the morning of the day when this consultation was to have taken place, Müller was found in his bed, lifeless, April 28, 1858. It is needless to say that the tidings of the sudden end of his laborious and valuable life caused profound sorrow in every part of the world where science is cultivated.

II

Having now considered the more prominent events of Müller's life and his career as a man among men, let us now consider more in detail the nature of Müller's work, its fullness and its limitations. Let us attempt to discover wherein it has proved so substantial a foundation for the later development of modern physiology; and lastly let us make ourselves better acquainted with Müller's strong person-

ality, as it was manifested in the home and among the ranks of his students and associates.

In the estimation of a man's prominence it is hardly necessary to remark that the importance which he may assume is always a relative quantity. It is first roughly drawn from a direct comparison of this individual with other individual workers. It is then tempered, as we may say, by a consideration of the relation of the individual activities to the whole field of knowledge existent at that time. There may be great physiologists, great morphologists and great systematists, but the criterion invariably to be used to determine the highest rank must ever be that comprehensive vision which, as Verworn remarks, is able to grasp in a single *Weltanschauung,* the whole breadth and depth of natural scientific inquiry—that comprehensive analytic and synthetic quality of mind which brings isolated unities of fact into concrete principles. It is from this point of view, and by these standards that we must judge the extent and quality of the work of Johannes Müller: first examine into the relation of his activities to the field of natural science of his day; and, secondly, ascertain the relative value of his work when compared with the labors of other men whom posterity has been accustomed to hold as leaders in the rank and file of natural scientists. And yet, before we can fully understand—much less appreciate—the intrinsic worth of any phase of Müller's many-sided activity, we must first take time to examine briefly the condition of the biological science just previous to the period of Müller's greatest work.

We have already in the course of our discussion made mention of the scope and value of Haller's work in physiology; yet we may be pardoned, perhaps, if, in the present connection, we again make reference to some of the more important characteristics of his period, which extended from 1708 to 1777, and closed something over half a century before Müller's began.

As Galen, in the second century, had shown his recognition of the practical value of physiological data and had laid as a basis of medicine, the practical knowledge of vital phenomena; as Harvey, by his brilliant discovery of the circulation of the blood, temporarily revived, after a sleep of thirteen centuries, the exact experimental method in physiology; and after many other investigators had made important, though isolated, contributions to the budget of physiology, we find Haller bringing together the extensive mass of facts and theories and establishing thereby physiology as an independent science which should pursue not only practical lines for the aid to medicine, but also undertake theoretical aims for their own merit. We find many theories and speculations in the air during the period from 1750 to 1830, the latter date marking the beginning of the period of Müller's greatest activity. As a result of the microscopical observations made in last part of the seventeenth century on the development of the ovum, the theory

of preformation was attracting wide interest. This had stimulated Caspar Friedrick Wolff to the production of his *Theoria Generationis*, which was unfortunately held in the dark by the opposition of Haller who could not accept the principles which led, at a somewhat later date, to the conception of Epigenesis. The theory of irritability was also a bone of contention, and though it was materially furthered toward the true conception by Haller's own researches, these last, unfortunately, served also to further a doctrine which thoroughly permeated and confused the development of all physiology down to the middle of the nineteenth century. This was due chiefly to the following fact: That the seeming impossibility of explaining the phenomena of irritability led to the welcoming of the theory of vitalism, or vital force, which asserted a distinct dualism between living and lifeless nature. The vitalists at this time (and nearly all the natural scientists, except perhaps Rudolphi at Berlin, were vitalists in a greater or lesser degree) were discarding the mechanical and chemical explanation of life phenomena, and were introducing such mysterious and inscrutable explanatory principles as *la force hypermécanique* and the *nisus formativus*. In this acute and exhaustive manner were explained even the most complex of vital phenomena.

Toward the end of the eighteenth century, however, some twenty years before the birth of Müller, a new note was being sounded from the ranks of German scientists, especially from Reil, whom we may well call the censor of German vitalism. In his work "Ueber die Seelenskraft," he was forcing upon unwilling hearers not only the conception that the life phenomena of living organisms are regulated by chemico-physical laws, but that there were higher principles in control which were present only in living matter. The few adherents to the chemico-physical hypothesis were, during the last years of the eighteenth century, receiving fundamental support from such men as Ritter, Galvani and Humboldt. Through the work of these men the notion was becoming popular that the galvanic current was the cause of all vital phenomena.

Among the chemical and physical discoveries of this time we can mention the advance of vegetable physiology through Ingenhaus (1730–99), who developed the theory of the consumption of carbon dioxide by plants; the discovery of oxygen by Priestley (1733–1804) and Lavoisier (1743–94), and the further discovery in this line by Girtanner, who showed that the venous blood is aerated in the lungs. Thus the existence of the mystical "pneuma," which had clung with a peculiar persistence to centuries of physiological thought, had now become a reality. The anatomical researches of this period were characterized by one discovery in particular, announced by Charles Bell in 1810; that is, the fundamental law of specific nerve physiology, to be later experimentally proved by Johannes Müller. In microscopy,

Spallanzani, Treviranus and others were dealing what we may call only the first of a long series of death blows to the hydra-headed theory of spontaneous generation, which was not eventually disposed of until the excellent work of Pasteur, over half a century later, and even now is often found lingering in popular scientific lore.

A consideration of these foregoing facts demonstrates to us that the greater number of these exact researches had been carried on in France and England. When now we turn with special interest to Germany, we find that her scientific thought had been fermenting in that powerful intellectual narcotic, the *Naturphilosophie*, which, under the great influence of Hegel at Heidelberg and Berlin, was stupefying every branch of accurate scientific research throughout Germany. Of the tendency of this movement to avoid the deductive method of research and to build up a conception of nature upon theoretical and speculative conclusions, we shall speak further. For the present, however, having gained some understanding of the condition of natural science, especially physiology, previous to the period of Müller's greatest activity, let us now consider more in detail Müller's relation to these movements, philosophical and otherwise.

Müller, as nearly every other investigator of his time, was a vitalist; but, as Verworn has said, "Müller's vitalism had an acceptable form." Although to him vital force was different from the forces of lifeless nature, its administration nevertheless followed certain physico-chemical laws. In this, Müller's conception seems to be modeled after the idea of Reil, the leader, as we have said, of the most rational form of the doctrine of vitalism in Germany. Müller maintained his position as a vitalist to the very end. He cherished to the last the thought of the existence of a "life energy." We well know how the activity of his pupils has apparently disproved forever this conception for natural science; and how it has led to the opposite extreme, the rather one-sided materialism of the present day.

When we turn to consider Müller's relation to the *Naturphilosophie*, we recall how he contracted this spirit while he was at Bonn, and how he was rescued, at least from its extreme influences, by Rudolphi at Berlin. Throughout his Berlin period, Müller devoted much of his thought to freeing natural science from the influence of the *Naturphilosophie*. The result was that not long after the death of Hegel, in 1831, the dangerous play with mystical words became gradually eliminated from the consideration of life phenomena. From this time on, the problems of living substance were furthered, especially by Müller, with the implements of comparative anatomy, of physics and of chemistry. In bringing about this condition, and in establishing the deductive scientific method as alone admissible in the realm of natural science, we must look upon Müller as a reformer whose work has been of enduring benefit to science. The nature of

his vitalistic hypothesis did not prevent him in the least from directing his labor to establish life phenomena on a physico-chemical basis. Even the vitalistic principle, as it appertains to the philosophy of the present day, is largely a matter of man's personal and ultimate view of his own life and his own destiny.

In our consideration of the relation of Müller's thought to the *Naturphilosophie* of his time, we must not deny the fact that Müller did recognize a grain of truth in the general philosophic tendencies of that day. As Verworn says: "While keeping constantly in mind the large problems and the goal of science, he regarded critically the special methods and questions only as means to an end—as means for arriving at a harmonious conception of nature." Throughout his whole life he remained steadfastly true to this philosophical conception of science which he had set forth in his inaugural address, "Concerning the Need of Physiology for a Philosophic Consideration of Nature." Verworn further laments that modern science has now so largely lost this element of philosophy, which it had gained as a result of Müller's treatment.

Having dealt thus far with the more abstract phase of Müller's activity and thought, let us now consider more concretely, for a few moments, first the extent of the realm over which Müller exercised so marvelous a command.

When we examine the list of 260 and more complete publications which have come from Müller's pen, we are better able to comprehend the universality of his activities; and it must be understood in this connection that in this great number there are few which represent merely a superficial dalliance with a possible line of investigation. They demonstrate, in almost every case, that Müller plunged boldly into the very heart of the matter which at the time received his fullest consideration. The main subjects to which his contributions appertain, include the following:

1. The Physiology of Motion.
2. The Life of the Fœtus,
3. The Sense Organs.
4. Dissection of Invertebrates; also
   (*a*) their development,
   (*b*) the histology of their tissues.
5. Nerve Physiology.
6. Animal Chemistry.
7. Human Anatomy.
8. Ethnography.
9. Comparative Anatomy of Vertebrates.
10. Physiology of the Voice and Speech.
11. Pathological Anatomy.
12. Systematic Zoology.
13. Paleontology.

It is clear that such an extent and variety of undertakings could not result from a single line of investigation, but required a universal activity which it is safe to say has never been equaled by any investi-

gator since Müller's time. A better conception of the degree of this extraordinary activity may be gained when one considers that Müller, from 1821 (when he was nineteen years old) to the time of his death, thirty-seven years later, produced, year in and year out, an average of one scientific article of from three to five pages, and with from one to three plates, every three weeks. And in none of these do we find the spirit of his work dictated by the desire to show that he could get some sort of a result out of this or that kind of investigation; but rather by the burning desire to survey and to understand the interrelation of all life phenomena.

It would seem that an unconquered field of knowledge left him no rest, and was for him a stimulus to activity just as much as was the knowledge of the existence of an unconquered people to Alexander the Great. At the first opportunity his attention would be directed to it, and never would the field be abandoned until its truths and its principles were at last incorporated in Müller's own system. This, for Müller, meant no simple undertaking. It included the universal proof, the definite transformation, the deepening, the enriching, the building up and the ordering of every detail of the work; so that from each such acquisition the greatest value to science invariably resulted.

This capability of Müller's is shown especially well in his work on the Echinoderms. He early applied himself to the study of the structure and habits of a single group of this interesting branch of animals. From this study he was led to consider the embryonic development, and, finally, having pursued his investigations in this line into four of the five orders of true Echinoderms, he culminated this great work by subjecting the organization of the entire class of Echinoderms, both recent and fossil, to a thorough revision. In this same thorough and exhausting manner, Müller attacked all possible points in the illimitable field of anatomical and physiological knowledge; and the insight into nature, gained through his own exhaustive researches, yielded to him a sureness of judgment which seldom failed him in the decisive moments of his career. An accurate personal knowledge lay at the bottom of his every work.

In the period of his greatest activity, when he was working simultaneously upon "The Development of the Reproductive Organs," "The Development of the Glands," and also the first volume of his "Handbook of Physiology," together with papers on "Osteology" and "The Myology of the Myxinoid Fishes," he must have possessed the ability to profitably divide his interest and to oscillate with a remarkable ease between these several objects of thought and investigation. The result is perhaps still more marvelous when we realize that, as a rule, Müller went over the same line of investigation three times: the second time while he was writing his results, and the third time when

the article was in the hands of the printer. Müller's manuscripts are said to have been the "terror" of all typesetters.

There was one peculiarity of this man of genius which, though perhaps a fault, no doubt favored the high degree of productiveness which Müller manifested throughout his life. This was his indifference to the formal completion of his written works. At the culmination of a certain line of investigation, in which he had arrived at definite, and usually important, results, he found too attractive the conclusions and speculations dependent upon these results, to spend his precious moments preparing or finishing his manuscript for the general reader.

Although Müller took, in the earlier part of his life, a certain interest in art, literature and music, it was usually the practical alone which was of consequence to him; and if this phase of the subject were once assured, he went forward in his work without much regard for the polishing or the agreeable rounding-off of his subject. And yet, had Müller lived under different influences and if he had dedicated to the superficial side of his work the same carefulness, we are bound to say that, like Cuvier, he too would have been a master of scientific style. But in spite of this tendency, in what Müller did write he was usually most thoughtful of the manner of his expression. He would sometimes read to members of his department, without disclosing the object, descriptions of certain forms to see whether or not he could awaken in his hearers the conception which it was his desire to implant. He was accustomed to enhance the value of his descriptions by forceful comparisons wherein the wealth of his imagination is readily recognizable. The dredging apparatus which worked before his laboratory window, the hood-like cap of Frau Martha, the little dagger of Cornelius, the sketch of Faust—all these common objects of his sight while hanging on the walls of his study were employed, as much else, for the elucidating of certain phases of the problems which occupied him at the time.

When we come to consider the nature and actual value of Müller's scientific work, it appears that in general he has more developed the principles set in motion by others, than himself given to the world epoch-making discoveries. In his teachings of the glands, of the voice, of the sense of sight and of the tumors, he has, with a tremendous power of work, heaped up an amount of raw material which not only became united in his own system, but has furnished a basis for much of the work in physiology since his time. It was Müller who first clearly recognized the interrelation of psychology and physiology. We remember that in his doctor's thesis he defended the position: "Psychology is nothing without physiology." In this regard Müller's own investigations, wherein he formulated his doctrine of the specific energy of the sense organs, demonstrated how fully dependent psychology might be upon physiology—a conception which in more recent times

has been developed so far as to arouse in many the belief that psychology should be taught as but a branch of physiology. That Müller saw so clearly the interrelation of these two branches of knowledge is decidedly a point in his favor. His theories were upheld, moreover, by the many facts presented in his works, "Concerning the Comparative Physiology of the Sense of Sight in Man and the Lower Animals," "Regarding the Phantasmal Phenomena of Vision," also "Concerning the Life of the Soul"; and many other references in his "Handbook of Physiology."

Another, and perhaps the greatest, debt which the world of science to-day owes to Müller is for his establishment of physiology upon a comparative basis. This conception did not first arise in Müller, however, but was previously expressed by his teacher, Rudolphi, who had already emphasized the motto: Comparative anatomy is the surest support of physiology. Grasping the fuller significance of this thought, Müller worked throughout his life to uphold the view that physiology can be only comparative; and among the vast number of his physiological works, there are few in which this comparative principle is not more or less clearly expressed.

A further consideration of the nature of Müller's work shows to us the evident necessity of making one concession; and yet one which, under careful examination, may not, after all, detract from the fame which the world accords to him. This is the fact that in spite of his varied activities Müller was never able to make what we may call a scientific discovery of the first rank. We can find issuing from his hand no single observation which, as has often been the case with other so-called great natural scientists, carries down with it through the ages the name of the fortunate discoverer. With the names of Priestley and Lavoisier will ever be linked the discovery of oxygen. The mention of the name Harvey immediately brings to mind the thought of the circulation of the blood, as with the name of Newton we invariably associate the statements of the laws of gravity. But discoveries of equal or even lesser importance can never distinguish the name of Johannes Müller. Even his excellent work on reflex action and the function of the anterior and posterior spinal nerve roots —these do not belong to him alone, for Charles Bell some years before had already promulgated the theoretical law; yet it remained for Müller to prove this law, and by nice experimentation to establish its universal application as a fact. Schwann presented to the world of science that noteworthy discovery that the animal tissue, just as plant organization, is composed of elemental cells; but it remained for Müller to show the highest importance attaching to this discovery, and to lay down the law of the correspondence between embryonic and pathological development.

This failure of Müller's to make a discovery of the first order can not, with justice, however, be made to count against him. As DuBois Reymond has said, "The most important discoveries can, and often do, play into the hands of insignificant investigators." "That Müller has no such discovery to his credit," continues DuBois Reymond, "can be called as little a failure as that a merchant, who becomes rich through industry and perseverance, should never have been visited by a great fortune." If, in the time when his productive strength stood at its maximum, instead of loosing his great power against a group of widely-extended activities, Müller had undertaken a course in a single definite direction, according to the view of Schiller, that strong stimulus would have been lost to the development of physiology.

Like Müller, Haller also, though he manifested an all-comprehensive knowledge of the field of physiology, failed in yielding an epoch-making discovery. Between these two men, as we have already noted, many points of similarity exist. But, notwithstanding the immense value which Haller rendered to science by his collection and ordering of the tag-ends of physiology up to his time (1775), his work as a whole is excelled by that of Müller with his over-weighing power of judgment and the massive comprehension which took in the whole realm of biological science. While Haller rendered an immense service by uniting the facts of physiology into a certain order and system, Müller took that system as he found it, worked it over, did away with every vestige of the false *Naturphilosophie,* deepened by his own exhaustive researches every channel of it, and turned into those channels the fresh spirit of a new physiology of comparative anatomy.

We come now, in closing, to a consideration of Müller's personality. From his father Müller inherited the strong and active body characteristic of the Müller line, which is traceable far back into German history. We can picture him a man of medium height; in his youth somewhat slim and of an elegant appearance; the breadth of his shoulders in good keeping with the well-shaped head, which was always held erect with a certain attitude of determination. Lithographs and photographs, pencil, pen and brush drawings presenting Müller's appearance at different times in life, have been given to the world; but, as one of his biographers has said, no picture could accurately repeat, now the sad, now the illuminating, splendor of that dusky countenance, with the dark locks of hair and brilliantly glowing eyes.

While we know that Müller received his physical characteristics from his father, it was from his mother that he appears to have inherited his mental qualities. Among these we may distinguish chiefly the strongly-developed sense of order and method, and the deep spirit of enterprise and of indefatigable activity. To these were added a thorough knowledge of men, a great gift of observation, a conscientious punctuality, and a firmness of purpose together with a knowl-

edge of the appropriate both in speech and in action. In his domestic life Müller appears to have been a true husband and to his son and daughters a good father. His home life was of the pleasantest —at least until the misfortune of ill-health in his later life.

As Müller's work as a whole is most comparable to Haller's, so we can say that his personality must have had much in common with that of Pasteur. In both we see the fine sensitiveness of mind, the same modesty in self-assertion, the same love of simplicity, the tenacity of purpose, the scrupulousness for details and the same religious devotion to the hardest labor: these attributes make up a character not altogether common in the general biography of the older school of natural scientists.

Müller's address was characterized by that stiff formality peculiar to the old school type of German professor; and yet with this he combined the dexterity and activity of the more modern scholar. His conversation was never productive. The constant consideration of the various problems of his activity was usually uppermost in his mind and, although he would talk pleasantly and interestingly of many varied subjects, as art, architecture and music, it was to some phase of his labors that the further discussion of these subjects almost invariably led back. And yet, in the circle of his own family, in a group of personal friends, or on his vacation and outings with his nets and microscopes, he could be the most congenial fellow, entering with enthusiasm into whatever duty, sport or pastime presented. Recreation for its own sake, however, Müller seems never to have desired. Yet in his earlier years at Berlin, he was seldom seen exhausted. In his later life, however, the intense nervous strain under which he worked was a source of much regret to his many friends; and the knowledge of his frequent use of opium and other alkaloids to bring him sleep a deeper source of sorrow to those who knew and loved him best.

As a teacher in the anatomical theater and in the class room, as also a guide of young investigators in the laboratory, Müller possessed an extraordinary ability. And yet, in the beginning he had no natural gift of speaking, no eloquence and no talent for foreign languages. Indeed, his early years as academic lecturer at the University of Bonn were, in this particular respect, not in the least promising. With constant practise, however, he was later able to develop a clearness in speaking, and a straightforwardness of expression, which, in itself, approximated to the gifts of eloquence, so that at Berlin he was considered one of the best of university lecturers. His delivery was never of the demonstrative sort, which held an audience spellbound by its bubbling vivacity, its ravishing fire of words, or through a kaleidoscopic blending of current witticism with scientific truth. He never went rambling in a lecture, either in thought or in person. His de-

livery was usually cold and calculating; and yet in some moments he could arouse, through his own deep earnestness, the highest enthusiasm among his students for the subject whereof he spoke—an enthusiasm, the fruits of which have been well shown by the works of the many students, afterwards famous, who received their first impetus from contact with Müller during his periods at Bonn and at Berlin.

In this regard, it is almost needless to say that Müller's position in Berlin resulted in a powerful influence over the younger natural scientists, especially in the northern part of Germany. His personality, as we have seen it, was one to attract students and to hold them when once they knew him well. He planned for them, and often accompanied them on many student trips throughout Germany and even into Norway and Sweden for the purpose of extending various phases of their biological study. In spite of his apparent coldness and constraint, he was, as DuBois Reymond has said, always a ready "comerade," and his views, his books, his apparatus of all kinds, were ever willingly shared with all who desired them.

To the same degree in which Müller was independent in his thought and work, he desired this quality in his students. In his relations with them, notwithstanding his thorough friendliness, it appears that in the laboratories Müller would seldom enter into an ordinary conversation. Regarding this point, DuBois Reymond says in his "*Gedächtnissrede,*" "The greatest reward for us students was when Müller relaxed and spoke in common conversation along the lines of highest pleasantry." Even before his fame as a leader in the field of natural science had gone abroad, and while dependent upon his worth as a teacher alone, he had constantly at his side a circle of eager students who clung to him with enthusiasm. Gathered about him in the earlier days at the University of Bonn, before he went to Berlin, one finds such men as Claparède, Haeckel, Lachmann, Lieberkuhn, Anton Schneider and Max Schultze. Upon his departure to Berlin in 1833, many of his students of the Bonn period followed him, and one need only mention the names of Haeckel, Ludwig, Bischoff, Schultze, Volkmann, Brücke, Helmholtz, Virchow and DuBois Reymond, to indicate the immeasurable significance which, as a teacher and leader of the young investigators of that time, Müller must have exercised. The lines of work which he established, his disciples and followers have carried out, and to what extent, we all realize—not as royal inheritors of that vast sovereign power of their master, but, we may say, as governors over the smaller territories into which, like the empire of Alexander, the field of natural science became divided after the death of its last great ruler. Of this famous group of students, now Haeckel alone remains, DuBois Reymond having died in 1896. Yet all these men, at some period of their lives, have rendered grateful

testimony to that common source of their first stimulus and earliest enthusiasm, Johannes Müller.

Look as we will through the history of natural science, we do not find an instance where a single individual, gathering about himself a body of select disciples, has by the infusion of his spirit of work sent abroad influences that have ruled so large a part of the territory of natural science. No such influence emanated from Haller, busily engaged in his collections and accumulation of the facts and theories of a century of physiological activity. Nor could it come from Cuvier, excluding from his circle of labor, as he did, the whole field of physiology and embryology, and preoccupied with his foibles of nobility. Nor was such influence from Darwin, secreted in the recesses of his study, modestly content to think, but not to speak. Nor from the combative Huxley, ever at the cannon's mouth with his evolutionary arguments. Nor yet from our more familiar Agassiz, with his noble retinue of followers, and a leader in our own popular thought of natural history though he was. These men have, it is true, been pillars in the development of the biological structure of the present time; yet their fields of labor have been most limited. But it was the nature of the case that it must be so, for no human individual, coming after Müller, could have the same grasp on the ever-extending realm of biological knowledge. Since his time there are few who have become masters of even a single territory.

In these days, when the scientific spirit is throwing its ever-increasing impetus into all lines of human activity, man has little opportunity to look back "to the mountains whence cometh his strength." The source of his to-day's blessings is either wholly overlooked, or, upon special occasions and anniversaries, is (with that feeling which Macaulay has called the "furor biographicus") made to glow in the colors of the sunset. Having avoided, as it is hoped, both of these extremes, we may quickly summarize what, for Johannes Müller, must ever stand as the criterion of greatness: With an all-including glance he was a master of the whole realm of natural science, which he widened until it became too great for its own government. With the certain power of genius, he studied the field of physiology, cleared away the rubbish, breathed into the earth his own spirit, and, in the end, left in the hands of his followers the thrifty seedling of modern comparative physiology, nurtured in the soil of an exact natural scientific method for the investigation of all life phenomena.

THE GENESIS OF ORES IN THE LIGHT OF MODERN THEORY

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IT is well understood, but often forgotten, that all the constituents of ore deposits are found in some form in the earth's crust, contained in more or less abundance in the rocks, especially in the eruptive rocks; and that they have been in some way collected from their disseminated condition in these rocks, and concentrated in veins, beds or other deposits.

Analyses of fresh eruptive rocks have demonstrated the existence therein of all of the ingredients of our valuable ores and their compounds. Few of them occur native like gold, silver, copper and platinum; and often, because of their minute quantity and fine state of subdivision, it is not possible to determine the precise form in which they are present.

The presence of sulphur, arsenic, antimony and tellurium indicates that there may be many metallic combinations in the eruptive magmas similar to those formed at later periods, nearer the surface.

The average composition of the earth's crust has been approximately estimated as follows:[1]

	Per Cent.
Oxygen	47.13
Silicon	27.89
Aluminum	8.13
Iron	4.71
Calcium	3.53
Magnesium	2.64
Potassium	2.35
Sodium	2.68
Titanium	.32
Hydrogen	.17
Carbon	.13
Phosphorus	.09
Manganese	.07
Sulphur	.06
Barium	.04
Chromium	.01
Nickel	.01
Strontium	.01
Lithium	.01
Chlorine	.01
Fluorine	.01
Total	100.00

[1] F. W. Clarke, Bull. U. S. G. S., 148, p. 13; J. F. Kemp, *Econ. Geol.*, I., III., 210.

Copper, lead, zinc, tin, silver and gold, although metals of great importance to man, constitute so small a part that their percentages are expressed by four to eight decimals, that is, between hundred thousandths and billionths of a per cent.

In some eruptive rocks, however, the percentage is much higher, and has been determined to be in the thousandths of a per cent. in the case of copper, lead and zinc, and one tenth to one hundredth as much of silver and gold.

The amount of metallic content found to occur as a primary constituent in unaltered rock is thus seen to be far too small to constitute workable ores, and indeed is often so insignificant as to be determined with difficulty. You all know that several per cent. of iron, manganese, zinc, lead and copper are required to make an ore valuable, the percentage varying, of course, with the locality, complexity of the ore and other familiar factors.

It is therefore apparent that a process of natural concentration is essential for the production of ore deposits, bringing into limited space the material formerly disseminated through ten thousand or a hundred thousand times that extent of ground, or accomplishing the same result by the removal of the admingled rock impurities.

Wherever this concentration is brought about by assembling of solid particles under conditions that admit of freedom of movement, we have placer deposits as of gold and platinum, of tin, iron and chromium ores, and sometimes of precious stones, such as diamonds, sapphires, rubies, garnets and others.

The ores found in veins, in disseminations throughout the rocks and in irregular shaped deposits in soluble rocks can not have been collected in any such manner. Their mode of occurrence and relation to the enclosing rocks make it evident that they have been slowly deposited from solution. And the only solvent of general distribution is *water,* with its varying content of acids and alkalies under changing conditions as to temperature and pressure.

Water is the magic instrument by which all the copper in Butte's vast mines, all the gold and silver of the Comstock and of Goldfield, were assembled; more potent than the Philosopher's Stone, more universal than the air we breathe; constantly at work, dissolving, transporting and redepositing. With indefatigable zeal and never-flagging industry it searches through the innermost recesses and penetrates the most closely locked chambers of the rocks, removing treasures through their very walls, and often repairing breaches made in the attack so skilfully as to defy detection, or to make the masonry stronger than when first laid. Small wonder that the ancients regarded it as one of the four prime elements!

But, although for several years water has been recognized as the

great agent in the formation of ore deposits, geologists are not agreed as to the source of this water, the conditions under which it is most effective, nor the relative importance of its work in ascending and descending movements.

Regarding its source, we have those who believe with John Woodward, Franz Posepny and C. R. Van Hise that the water in the uppermost layers or outer zone of the earth, including the waters on the surface and in the atmosphere, accomplish the formation of ore by means of a perpetual circulation. From the air it falls on the earth as rain; through crevices and fractures it enters the rocks by reason of its head or the weight of more water on top of it, and finds its way deeper and deeper to the very lowest point where the density of the rocks will permit it to penetrate. Down to this depth, which is theoretically not more than five or six miles, the temperature has been constantly increasing, and the water by reason of this higher temperature has been gaining strength as a solvent and picking up alkalies or acids that enable it to hold even the most difficultly soluble substances in solution. Finding no escape downward, and urged on by cooler and heavier waters above, these saturated solutions begin to move laterally and upward, expanding and becoming of lower specific gravity because of the forced deposition of dissolved material as they become supersaturated. Following the directions of least resistance, these metal carriers reach the surface as hot springs or geysers through fractures caused by earth movements. Gradually the walls of these fractures become coated with vein minerals and ores, until the waters stop flowing or the fracture is healed and a vein is formed.

Then there are those like Vogt, Spurr, Weed and Kemp, who maintain that the chief source of underground waters is the unconsolidated magma of molten lava within the earth. These authorities point to the immense volumes of steam emitted from volcanoes; they call attention to the conclusions of European scientists who have decided that many of the hot springs can not be derived from meteoric waters heated and returned to the surface; they remind us that there is so much watery vapor derived from lavas that possibly the oceans themselves were formed from volcanic emissions. They point out the ease with which such waters, thus derived and so heated, could gather metallic substances at great depths and bring them to the places where they are now found. They mention the fact that there is a very general association between the more important mining regions and eruptive rocks; and they raise several serious objections to the premises of the disciples of the meteoric water school.

On this particular point we shall not dwell further; it is quite probable that both theories contain elements of truth; and that ore deposits have been formed by both magmatic and meteoric reascending

waters. It is even possible in some cases to determine by the character of the minerals the origin and nature of the causative solutions.

As to the relative importance of the work of ascending and descending waters there is also divergence of opinion. There are few who still doubt the agency of descending waters in the formation of the oxidized ores, such as carbonates, silicates and oxides of copper, lead and zinc and silver chloride, or in the superficial or shallow alteration of the sulphides, arsenides or antimonides. The iron ores of the Lake Superior region, for example, are generally believed to owe their concentration to descending solutions, in this respect differing from many of the Scandinavian iron ores, according to recent descriptions.

It is not, however, the oxidized or "dry" ores alone that are now believed to owe their formation in large part to the action of descending waters; but the base ores consisting of chemical combinations of the metals with sulphur, arsenic, antimony, tellurium and some rarer elements. It is only within the past decade that it has been considered possible that the sulphide minerals are produced by reaction between sulphate or carbonate solutions and undecomposed sulphides or other minerals found in veins. Laboratory experiments have, however, shown that the operation is not only possible, but easily accomplished and duplicated under normal conditions as to temperature and pressure.[2] This is a fact of great importance and wide significance, for it aids in the explanation of many formerly puzzling phenomena of mines and mining geology.

It has long been noticed by the students of ore deposits that by far the greater number of mines become exhausted at comparatively shallow depths; that veins, instead of continuing downward uniform in size and composition, like dikes of diabase and porphyry, become smaller and of lower value with depth, and often disappear altogether. It is noticed also that the shape of many ore deposits and the distribution and paragenesis of the minerals which they contain can often be better explained on the theory of descending than of ascending mineralizers. Moreover, it is apparent that there are changes constantly in progress in those portions of sulphide ore bodies lying nearest the surface of the ground. These changes consist in the oxidation of the sulphides and their solution as sulphates. These sulphate solutions percolate downward into the veins or rocks below along the most open channels; and thus, by degrees, the upper zone of the vein is robbed of most or all of its sulphide minerals, and only a gossan or iron cap remains.

The process of oxidizing and leaching out of the sulphides in the superficial zone of ore deposits tends, first of all, to disguise the nature

[2] H. V. Winchell, "The Synthesis of Chalcocite," *Bull. Geol. Soc. Am.*, Vol. XIV., pp. 269–276, 1903.

of the unaltered ore below. In many instances the ore discovered from the outcroppings is gold ore. And gold mills are often erected and operated for years upon such ore, without a suspicion arising that extensive bodies of copper or lead sulphides occur at greater depths. Such was indeed the history of Leadville, Colorado; of Bingham, Utah; of Ely, Nevada, and of Mount Morgan, Australia. The latter is one of the world's greatest gold mines; yet it is now producing copper from its lower levels; and developments have proved it to be a great copper mine. Immense low-grade deposits of copper ore are found below the gossan at Ely and at Bingham, although it is doubtful whether the most experienced geologist or keenest observer of mineralization phenomena would in either place have felt justified in predicting the existence of the wealth below.

In other localities the metal values have either all been removed, or else the primary sulphide ore was too poor in gold to leave oxidized ores of value. In such cases the discovery of the subterranean treasures is purely fortuitous. Butte may be considered the most conspicuous example of this class. The outcrops of its copper veins contain the merest traces of that metal; and there is seldom enough silver or gold in them to justify mining even under the low costs obtaining there to-day. The zone of oxidation is generally from one hundred to two hundred feet deep; and if it had not been for the presence of another system of veins carrying silver, veins of different age and origin, but closely associated geographically, this greatest of copper camps might not yet have been discovered. It was in the search for silver ore that copper ore was discovered here, and one can not help wondering how many more camps equal to Butte may be undiscovered and unsuspected where no outcropping silver or gold mines attract the prospector, and reward the efforts of the miner. Here is surely an important and unexplored field for the geologist. The study of oxidized vein phenomena may yield results thoroughly satisfactory from both material and scientific points of view.

Below the zone of oxidation the chemical reactions which take place between the descending acid solutions and the unoxidized ores result in the formation of more and richer sulphides, down at least to the level of the lower limit of free circulation, and as far as surface waters penetrate. And as erosion of the surface is continually bringing deeper and deeper sulphides within the reach of oxidizing and dissolving surface waters the operation is in constant progress, and these lower-lying ores become more and more enriched until in some cases are formed bonanzas of world renown, and almost inestimable value. It is a fact of much significance that such bonanzas are generally limited to depths where descending waters may have penetrated at one time or another. Indeed the very channels through which the enriching

solutions came can often be detected; and peculiarities of shape and position observed which can be explained with difficulty on any other theory.

Practised miners often point to the richness of ore shoots near the junction or crossing of veins. Indeed such pockets and shoots are usually sought and frequently found where two veins come together. This fact alone may not signify the instrumentality of downward moving waters. But when in connection with it we discover that rich ore shoots are also frequently found at the intersection of veins by faults, and zones of movement so recent or of such shallow depth or limited extent that the faults themselves are not veins, and have not been mineralized except near the intersected veins, and when the ore shoots thus formed occur on that side of the fault plane where they could have been formed most naturally by descending waters, and are wanting entirely in the corresponding place on the other side, then, indeed, we recognize beyond a doubt the agency of meteoric waters in both situations.

It is often possible where sulphide ores have been deposited in soluble rocks to distinguish between the products of ascension and descension, and here too the latter are frequently of much the highest grade.

This theory of secondary enrichment which is so frequently referred to in recent mining literature; and is still so little understood, depends, of course, on the existence of a body of primary ore, probably formed by ascending solutions. If there are no ores to be oxidized the downward moving waters will have no metalliferous burden to deposit. But wherever the rocks contain disseminated ore, no matter how small the percentage, there is a possibility of the formation of richer ores through the action of surface waters. And where the primary mineralization was itself comparatively rich, even though not a minable product, there the downward-moving waters may the more readily bring about concentrations of high-grade bonanza ore.

Bearing in mind this conception of the meaning of "secondary enrichment," and admitting that it is frequently accomplished through the agency of descending meteoric waters, let us briefly consider the conditions under which they are most active and efficient:

It is a proposition requiring no argument that if by the aid of mineral bearing solutions the ores occurring in veins are to be enriched, these solutions must enter the veins. And if all the meteoric waters which fall upon the outcrop of a vein or upon rocks containing disseminated ore run off rapidly down the mountainside without remaining to oxidize, dissolve and penetrate the vein with their load of mineral, there can not be any enrichment caused thereby. Furthermore, if the work of the surface waters is chiefly destructive mechan-

ically instead of chemically there will be little opportunity for the deposition of secondary concentrations of ores within the rocks. If, for example, the principal effect of the rains and snows is to erode and wash away the exposed portions of veins with all their contained ores, there will be a scattering and wasting instead of an assembling and storing. In other words, secondary enrichment by descending waters depends first of all upon *the ratio of oxidation to erosion.* Where erosion is more rapid than oxidation the unoxidized sulphides will be found in the rocks and veins at the surface of the ground, and in the sands rolling down the beds of torrential streams as in Alaska. While if oxidation precedes erosion the uppermost zone of a sulphide ore deposit will be oxidized and leached of its base minerals, as is the case here in Butte, and to varying extent over the larger portion of the temperate zones of the earth. Assuming that the conditions are such as to permit the entrance of surface waters, and that the ground-water level is at some depth, which depth naturally varies from year to year and age to age because of many common geological phenomena, the factors upon which depend the extent of secondary enrichment are: (1) Quantity of water, (2) time, (3) temperature, (4) the physical structure and solubility of the rock containing the primary ore, and of the ore itself.

It is manifest that a large supply of mineralizing solution will accomplish greater results than a small supply, provided it follows the course of the ore. For the metals in solution can hardly escape precipitation by reaction with the primary sulphides present, sooner or later, at some depth; and the oxidizing and dissolving effects will certainly increase with the amount of active oxygen-bearing moisture available. In regions of very little rainfall there may be partial oxidation to the depth of several hundred feet; and yet there may still remain particles of the primary sulphides upon the very surface of the rocks. Chemical activity is great; but the thirsty rocks quickly absorb that part of the water of rains and melting snows which is not evaporated, and the work of oxidation is not so complete as in regions more plentifully supplied with rain. On the other hand, there may be such heavy and constant downpourings of rain, even in tropical regions, that erosion is again the most active agent.

The second of our factors is *time;* a commodity of which the geologist is accustomed to make most liberal and even extravagant use in his arguments and theories. In this he is frequently justified; and the most astonishing results may be produced by the long continued but slow operation of natural forces in any given direction. Events of the past few years have, however, reminded us forcibly that catastrophic phenomena must not be forgotten in comprehensive reviews of the earth's history.

The time element enters in a variety of ways into the problem of ore formation by descending circulations. Thus an ore deposit formed in its primary, low grade constitution during earlier geological periods, such as the Cambrian or Huronian, and during all of the subsequent ages exposed to the action of superficial agencies unhampered by subsequent covering of later rocks, has a thousandfold the opportunity for concentration of its ores that is presented by similar rocks and ores formed during later geological epochs, say the Tertiary. This is exemplified by the iron ores of the Mesabi range as contrasted with the glauconitic deposits of New Jersey or Texas. During almost all the ages since the Cambrian the iron ore formation of the Mesabi has been exposed to the weather, covered only for a geological moment during a part of Cretaceous time. The result is the largest and purest deposits of iron ore ever discovered, while rocks of similar composition but much more recent formation exhibit only the initial stages of ore formation.

Another way in which time affects ore deposition is in connection with the rate at which the waters move in a vein. Solutions of a given composition may move so rapidly as to produce but little effect, or may move so slowly that they clog up or retard other active waters after their own power is exhausted. Upon a steep drainage slope or mountain the waters may pass off so rapidly, even below the actual top of the ground, as to exert but little influence, or they may move with just sufficient rapidity to accomplish their maximum of chemical effect.

Our third factor, *temperature,* is of great importance. In the first place, oxidation, which is but another name for combustion, is greatly accelerated or retarded by slight changes in temperature. Sulphides which remain immersed for centuries in water under a glacier in Alaska would be completely oxidized in a few years exposed to the heat of the sun on a southern slope in Colorado or California. In the next place, the rate of solution depends directly upon temperature, increasing as the temperature rises, and, itself a process of heat consumption, is greatly facilitated by heat from external sources. Thus in warm rocks, in mild climates, upon the sunny side of mountains, there will be the most favorable conditions as regards temperature, for the formation of secondarily enriched ore deposits. The experienced prospector will tell you that it is in precisely these localities that they are found, although he never before heard any explanation for it.

Lastly, the physical structure and solubility of the rocks and ores affect their susceptibility to later enrichment for perfectly obvious reasons. A dense rock is not readily entered by mineralizing solutions. Likewise an insoluble one is not easily replaced and does not afford lodgment for ores. And if the ores themselves are not readily attacked

by oxidation or by solvents, the quantity, time and temperature may all be sufficient to accomplish great results with more tractable ores, but have practically no effect upon these refractory ones. A good example of this again is found on the Mesabi range where the heat of an eruptive rock has so altered a portion of the iron formation for many miles that it has resisted surface solution and concentration, and is a worthless low-grade mixture of rock and magnetic ore still; while away from the influence of the eruptive, have been formed the iron ore deposits which have given to the iron and steel industry of this country the raw material required to make us preeminent in the markets of the world.

Reduced to more simple language and ideas the foregoing remarks amount to a statement that climate, sun, rain, average temperature, topography, depth of soil or surface débris, erosion, glaciation and other common and often unobserved influences and conditions have decided bearing upon the important question of ore formation.

These are the phases of our modern theory that have received little attention hitherto; and are yet of practical value that can hardly be overestimated. We find few bonanzas of high-grade ore in Siberia, Russia, Alaska, British Columbia, Washington or northern Ontario. Our theory tells us why they are not to be expected, and why such enriched ores as are found seldom extend downward to great depths. We turn to regions of milder climate, less glaciation, gentler topography, and we find the rocks altered and softened and oxidized to some depth below the surface. We find that the veins wear "iron hats"; and beneath them we find bonanzas reaching to great depths. We find our best ore shoots on the sunny sides of the mountains, while the veins on the northern shaded sides where the snow lies till mid-summer and the rocks are cold produce no such rich ore. We begin to realize that our theory is based on fact and proved by observation; and that it justifies us in placing confidence in it, and in acting upon it within reasonable limits. And we marvel that facts so simple and of such easy comprehension and yet of such practical value should receive so little attention from the writers on ore deposits.

THE RELATION BETWEEN RECENT INDUSTRIAL PROGRESS AND EDUCATIONAL ADVANCE

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WRITERS and students who have turned their attention to educational problems have almost without exception given adherence to what may be called the "great-man" theory of educational progress. They have maintained the thesis that educational advance has been chiefly, if not wholly, due to the efforts and the perseverance of certain great personalities, who have pushed their particular contribution upon a reluctant public, by the sheer force of personal ability and merit. During the first period of great educational activity in the United States, according to this theory, our educational progress was attributed to Horace Mann, Henry Barnard, James G. Carter, Samuel Lewis and others. Without in any way depreciating the value of the labors of these able and earnest men, it is just and proper that recognition be given to the underlying social and economic conditions which produced the situation that enabled them to carry their propaganda to a more or less successful issue; and which, indeed, indicated to them the need of such works and filled them with the zeal and ardor necessary to carry them out in the face of determined and powerful opposition. Mann and his associates exercised a "directive," as Lester Ward expresses it, influence; but a further search must be made for the "impelling" forces. Only when the student comes to the more recent period of manual, scientific and commercial training, and of recreational education, does he find any important recognition of the underlying influence of social and industrial changes. Even in this period little has been done except to point out in a general and casual way, the fact that industrial progress and the growth of cities have led to many hap-hazard additions to the curriculum, and have been the real cause of bitter conflicts between the "reformers" or "fadists," and the "conservatives." The reformer, educational or otherwise, is a product of his time; if he is successful, it is because he has, in a measure, correctly interpreted the hitherto vague and undefined demands of the classes of people which are rapidly rising in influence and importance.

The many striking and important social and industrial changes which have occurred during the last two or three decades, make many new demands upon our educational system. In recent years the broad

conception of education as a lifelong process has been generally accepted. It is no longer conceived to be solely confined within the walls of school, college or university. Many different agencies,—the home, the playground, the press, the pulpit, the lecture platform, the library, the labor union, the store, the shop, the farm, the office, the society—all supplement and complete the work of the school. In considering the duty and work of our public school system at the present time, or at any other period, attention should be paid to the functions which these other institutions are able to perform at the time under consideration. The school is normally a time and labor-saving device, as well as an institution which forms the character and aids in the development of the individual, and in the progress of society. It should convey to the student the accumulated experience of past generations, it ought to show the significance of his daily experience, and coordinate the latter with his studies and investigations; it ought to train him so that he can and will wish to continue his education by the aid of these other secondary educational agencies; and lastly, but not least, it should attempt to supply any deficiencies which change may develop in any one or all of these other agencies. The real function of the school is to adjust the individual to his environment—physical, industrial and social.

In the study of educational problems at the present time, two important, but often overlooked or neglected, facts confront the investigator. In the first place, the social environment, the sum total of influences which bear upon the life of the individual, has been increased in extent; in other words, the entire world has been drawn closely into touch. People, intelligence, goods, now come from and go to the most distant parts of the globe quickly, surely and regularly. On the other hand, occupations and certain characteristics of home life have changed so as to tend to produce narrow views of life, and to confine the vast majority of individuals within narrow grooves of action and thought; the tendency is to cause him to live in "parenthesis," disconnected from the great world of thought and action. While modern communication and transportation, and world markets demand a broader life and tend to produce broad, liberal views of society and of the world; occupations have been specialized and subdivided until the life of the majority of individuals is cramped. Our daily work and home environment, whether rural or urban, tend to contract and astigmatize our view at the very period when democracy and the idea of a community spirit should thrive and be actually transformed into a reality. This is indeed a grim paradox of modern industrial life.

The earlier forms of industry gave the worker a relatively broad outlook; division of labor and specialization of industries tend to narrow this vision. As the division becomes more and more minute,

the production of goods requires the cooperation of a constantly increasing number of workers. Each one forms but a link in a great industrial chain, and consequently sees only a minute part of the entire operation necessary to make the completed article. Machine production aims at making a uniform and interchangeable product. The workman is unfortunately bound down to a rigid and monotonous routine; he becomes in time almost automatic in his movements. He struggles blindly on, working and producing, without recognizing the end in view, without feeling that he, himself, is an integral and necessary factor in the formation and operation of a great industrial machine or organism.

The school must aim to demonstrate the social necessity of each worker's task, and to give a clue to the great, intricate industrial labyrinth. The problem of the relation of labor to capital can not be solved until the work and function of all factors of production are clearly understood by a majority of the people; when such a condition obtains, the question of the proper distribution of wealth will be greatly simplified. The school attempts to meet the new economic condition by enlarging its curriculum; it now aims at more than mere mental training and discipline. Manual training, nature study, kindergartens, athletics, physical training, commerical training, agriculture, domestic science, cooking, sewing, drawing, modeling, painting and music are now incorporated into the course of study. These added features are merely tentative attempts to give training which was formerly provided outside the school, but which can not be so provided under present conditions. Much of this work has been added in a haphazard manner, in order to fill a vaguely defined need, without proper arrangement or agreement with the older portion of the school curriculum. These additions, the direct result in many instances of a vigorous popular demand, have increased the importance of the school, and have made it a more potent factor in the industrial, economic, and social progress of this country. Nevertheless, after this enlargement and enrichment of the course, there still remain many gaps in our educational system which are yet to be bridged over.

The order in which these additions have taken place is fairly well defined. As scientific discoveries and the practical applications of steam and electricity multiplied, our industrial methods underwent an almost complete transformation. A universal need for scientific and technical knowledge was felt. The first notable change from the time honored curriculum was made in response to this demand. The physical sciences, physics and chemistry, were advanced to a position of equal rank with mathematics and language. Next appeared a demand for the kindergarten, manual training, drawing and domestic science. This demand is the result of a conscious or unconscious recognition

of the undesirability of a wide separation of hand work from head work, aided by the call of manufacturers for young men possessing trained hands and eyes. The need of such training was not urgent previous to the wide-spread development of the factory system. Treading on the heels of the manual-training movements came physical training, night and vacation schools, training for citizenship, nature study, school gardening, the study of agricultural science, and the special school for the truant and the "incorrigible." Not all of these additions to the work of the school are to be found in any one system, but each has been somewhere recognized as a desirable feature of the educational program. In general, it may be affirmed, that as a people pass from a semi-primitive agricultural stage with isolated, nearly independent families, to the more complex industrial life involving mutual interdependence and specialization of occupation; the importance of the education gained within the school increases relatively to that acquired outside.

What is the significance of these changes to society? It seems indisputable that the importance of the school relative to that of the home in the education of youth, has increased and is still increasing. This fact grows naturally out of the changed functions and environment of the home of the present as compared with that of immediately preceding generations. Home training is highly individualistic; school training is not. The state educates the young in order to advance the welfare of society, in order to form the good citizen—the efficient producer and consumer. The desired result is the elevation of the standard of living of society—a social benefit. The mass can, however, be elevated only by acting upon each individual composing it. The school becomes society's agent for the promotion of its collective welfare; its purpose is chiefly directive. As society is recruited from the young, it is necessary that the incoming generations be worthy successors of the outgoing. The attention should be fixed upon those institutions which train the growing child, and not so much upon those corrective and repressive institutions which are needed because the early training and direction of their inmates were not what they should have been. Too much money is spent upon the diseased tree, but not enough on the growing twig. The functions of the school should include the intellectual, physical, industrial and moral training of the young, and of the older persons as well; the greater the efficiency and effectiveness of the school, the less the need for corrective and repressive institutions.[1]

The cure for many industrial and social ills is to be found in the proper use of increased leisure which improved industrial methods make possible, and which the modern ideal of democracy proclaims to

[1] See article by the writer in *Education*, October, 1903.

be the birthright of each and all. Leisure makes possible study, social intercourse and the expansion of the life of the individual to the measure which the modern world community spirit demands.

At the beginning of the last century, the United States was a weak nation possessing an unknown immensity of undeveloped resources. In a century it grew to be one of the richest and most powerful nations of the earth—an acknowledged great power. Development of resources was the demand and the necessity of the period. Exploitation of natural treasures and constant expansion was the program of the century. Resourceful, self-reliant and individualistic men who were willing and able to devote untiring energy to the task of building up the material strength and resources of the nation, were needed, and became the familiar, successful and progressive type of American manhood. The fundamental, all-absorbing economic question was production, which was carried on chiefly through the exploitation of natural resources. The rough and crude form of frontier life reacted upon the entire people, and left an imprint which many generations will not entirely eradicate. As long as the frontier remained there was continual contact with the new and primitive. This type of civilization tended to continue and to perpetuate itself long after the conditions which caused it had passed into history. The primitive type of society is highly individualistic; it resents the interference of organized society in any form. In such a community might often spells right. It places little or no limitation upon the use or abuse of property. The right of the individual completely over-towers the right of society.

After the disappearance of the frontier a different set of conditions confronts the people of the United States. Widely separated farming communities or sparsely settled mining districts, and the presence of immense tracts of practically free land, demand one system of ethics, one code of human relations, and one kind of educational principles and precepts; while densely populated cities, the scarcity of free land, and increased mutual interdependence make imperative a new scheme of social relations. The disappearance of the frontier induces a weakening of the individualistic and a strengthening of the social qualities of the American people. Sociological, as well as psychological, principles begin gradually and timidly to creep into the educational world. Society must adjust itself to a more crowded environment; and the problem is to make this adjustment along the lines of least resistance. New social, industrial, agricultural, commercial, educational, ethical and legal forms now become necessary. What is desirable and even highly commendable in a new, fertile, undeveloped and expanding country may become a positive menace and hindrance in an older, better developed and more densely populated nation. New aims and new ideals are requisite to this adjustment from the old to the new. Educa-

tion now assumes a position of greater importance than it held in former generations. Changed environment, crowded cities, more intensive and more scientific agriculture, quicker and more regular methods of transportation and communication are producing effects which are plainly noticeable in the life, thought and action of the entire nation. It is, however, extremely difficult for a people schooled for generations in the university of self-reliance and of individual liberty to graciously accept the restrictions and modifications which this new era makes necessary; but such acceptance is inevitable. If education lags behind, rather than precedes, this changing sentiment, if it is merely passively carried along with the stream, instead of actively aiding in controlling its progress and direction; it fails utterly to effectively perform one of its most important duties—that of minimizing the friction of readjustment to a new environment and a new set of social and industrial conditions. This need of adjustment should be recognized by educators, and intelligently dealt with.

The men of the present are not Robinson Crusoes, they live in a busy world peopled with millions of other similar fellow creatures. An individual is what he is because of the existence and influence of other men; he is distinctly a social product. Development of the individual is the resultant of individualistic and of social demands; but the latter are now beginning to take precedence over the former. Purely psychological and individualistic needs and desires must more and more be modified by those of a sociological character. Society is a complex and delicate organism or piece of mechanism; the wishes and ambitions of the individual must, in an increasing measure, be subordinated to and dovetailed into, the needs of society considered as a whole.

The disappearance of the frontier leads to the gradual elevation of the moral tone of the people. It is an important factor in assigning greater importance to questions of distribution and consumption. Business and political ideals are higher to-day than formerly. Many political methods which were in vogue as late as 1896, are not considered to be in good form to-day. The doctrine that property is a social trust is gaining ground as it could not have done twenty or forty years ago. We are examining closely the methods employed in wealth production. The monopolist and the men of great wealth are now put on the defensive. Each must justify the social utility of his industrial power or his amassed fortune. Race solidarity and the brotherhood of men are now shibboleths. This spirit of brotherhood is first manifested between members of the same trade or society—comparatively small groups; but gradually it enlarges its scope and becomes more inclusive. To-day the laboring man is found preaching the solidarity and mutual interest of all workers in the United States—skilled and unskilled alike. A great strike is conducted upon a clear recognition of this

principle, one which could hardly have risen into consciousness if a great mass of fertile and easily accessible land was still our national heritage. Such a change as this calls insistently for new ideals in education.

America is an enormous assimilative cauldron. Here are gathered nearly all the tribes and peoples of the earth in one great heterogeneous mass; and the public-school system is the official assimilator. It deals with the young and plastic. Excepting those who attend private and parochial schools, our laws bring all the children of the entire country under the influence of the public school system. The immigrant comes to us from an entirely different environment; he has developed under different influences. His home life is not the same as ours; his child possesses other concepts, traits and ideals than those of the American boy or girl. The process of assimilation usually means the molding of this people in conformity to the so-called Anglo-Saxon cast. It is forgotten that these people have many characteristics and traits which might well be grafted into our civilization and thus perpetuated. Miss Jane Addams has done much to emphasize this important fact. She points out that it is characteristic American "complacency" to utterly ignore the past experience of the immigrant who comes to our shores. Earnest Crosby makes the indictment more sweeping and severe: "And not content with stifling the originality of the immigrant, we must needs carry our missionary zeal for uniformity to foreign lands in the hope of destroying all individuality. In Anglo-Saxonizing India and Japan we are crushing out the most wonderful of arts beyond a possibility of resurrection. We are the Goths and Vandals of the day. We are the Tartars and the Turks. And the countries which we overrun have each their own priceless heritage of art and legend which we ruthlessly stamp underfoot." Some attempt certainly should be made to preserve and continue the desirable traits and gifts of the different alien peoples who crowd to our shores; and to assimilate these traits into the sum total of our national characteristics. Few educators have as yet seen the possibilities and the desirability of progress in this direction.

It should be noticed that not until after our frontier was practically a thing of historical significance only, did the immigration from Southern Europe begin. These people lack individual initiative; they live in little communities. With the rise of modern industrialism and of urban life, our civilization took on aspects which were attractive to the more docile and less individualistic emigrant of many sections of Europe. The traits of these people are more nearly consonant with the life of to-day than that of the early individualistic Anglo-Saxon frontiersman. The assimilation of these races and of their culture may modify our civilization and traits in a very desirable manner. A Greek

immigrant, in a letter recently published,[2] clearly states the proposition. "In this country there is a great movement against the foreigners and especially those of Latin, Slavic and Jewish origin. The Latin and Jew (altruist and sentimentalist) will give in this country some of their qualities that the northern people don't have. The Americans (egoists and individualists) need some of our blood to change their character in the next generation." There is, however, another side to this question which will be touched upon later.

The rapid growth of cities has been a marked feature of recent growth and development. The city of to-day is the result of a rapid and unhealthy growth. People have been rudely drawn from a rural environment and quickly sucked into these great uneasy vortices of industry and trade. The ideals, customs and habits of the rural community have gone with them to this new environment, and still cling with great tenacity. Only in recent years have the city dwellers awakened to the fact that they are really dwelling in an environment which calls for new, non-rural rules of action and of association. The nature of the city itself has been modified. It is larger, more crowded, more dependent upon arteries of trade and transportation, and upon the supplies furnished from the outside. The race must adapt itself to urban conditions as they exist to-day; we must learn to live and to thrive in densely populated centers. If the United States is to continue on its present course of advancement and progress, the city must be made clean, healthy, moral, and it must be well governed. The majority of the successful business and professional men of to-day were born in rural districts. In the past the country has furnished the bone and sinew of the city, and, as a necessary consequence, it has been drained of many of its best and most progressive citizens. The city can not indefinitely continue its parasitic existence. Already one third of our population are urban dwellers. A much larger percentage of our successful and progressive men and women must in the future be drawn from the city-born and city-bred population; hence, the urgent need of improved conditions in our cities.

The modern city is a mere industrial establishment; but it must be made a cluster of homes. Healthy and wholesome home surroundings can only be obtained through education as to the sanitary and esthetic requirements of urban communities; and these efforts must begin with the child. The cities have been "great sores upon the body politic," because they have experienced such a rapid development that society has been unable to modify itself rapidly and sufficiently to meet the requirements of the situation. A two-fold weakness of our educational system is revealed at this point. The curriculum and the methods of the city school have not been sufficiently modified to meet the require-

[2] *Arena*, March, 1905.

ments of children, living in a crowded city, with little opportunity for constructive work or healthful recreation. Some progress has been made in this direction; but there is still great need of further improvement. On the other hand, the rural school has assisted in augmenting the growth of the cities and in encouraging the drift away from the farm. Its curriculum has absolutely ignored, with a few very recent exceptions, the fact that the farm presents problems which require education and training to solve. "Every book they [the country children] study leads to the city; every ambition they receive inspires them to run away from the country; the things they read about are city things; the greatness they dream about is city greatness." The problems connected with the city, those relating to labor, and all our great industrial and social questions, are at the root questions of education.

However, after the faults of the city have been examined and laid bare, it is but just to recall that the cities have ever stood in the forefront of the educational advance and in the development of labor organizations. Our free tax-supported schools, for example, originated in the cities. A striking illustration of the position of the cities is found in the result of the referendum of 1849, which established free schools throughout the state of New York. Forty-two out of a total of fifty-nine counties favored the repeal. Of the seventeen counties which stood firm and won a victory for the tax-supported public school, four were included in, or were directly adjacent to, New York City, eight bordered the Hudson between Albany and New York, and three others contained the important cities of Buffalo, Syracuse and Schenectady. The vote revealed a sharp division of urban against rural counties; and the former stood for progress and for better educational facilities. Without entering exhaustively into an analysis of the situation, five reasons may be assigned for this phenomenon which is by no means confined to the Empire State: (*a*) A large percentage of our city population are industrial workers who are small or non-taxpayers. (*b*) In the large cities are found great masses of accumulated wealth which can be taxed. (*c*) Here the home first lost its industrial character and its surrounding playground, and as a result much of its educational possibilities. (*d*) People are crowded closely together in cities, evils and needs are more in evidence than in rural districts. Also, the opportunities for agitation and propaganda are more numerous. (*e*) Pauperism and juvenile crime are more prevalent and disturbing in cities than in the country.

Industrial progress has brought about the separation of the workers into distinct, well-defined classes; particularly marked is the division between the manual workers and the brain workers or the managers of the business. Professor Veblen remarks that the progress of in-

dustry has relieved one class of workers, "of the cares of business"; and they "have with increasing specialization given their attention to the mechanical processes involved in the production for the market." The remarkable increase of the indirect method of labor is a factor in the modern industrial problem. The workers no longer produce directly to satisfy their own wants; each produces for others, while all furnish something for each individual. It is a round-about process; the connection between effort and satisfaction is hidden. The direct reaction between effort and satisfaction has been superseded by a very complex social and industrial chain of actions and reactions. The worker often becomes a drudge, a drone, an unthinking piece of mechanism, partially because he does not recognize or feel that his work has any social significance, because there is little apparent causal relation between effort and wages. Industry has been "depersonalized."

Modern specialization of industry, diversification of demands, and increase in the variety of consumption have tended to divide the population into a large number of classes and interests. Progress has always resulted from class struggles, the clash of interests; but to-day the form of this contest has become complex. There are the familiar traditional classes—land-owners, manufacturers, merchants, professional men and laborers; but each one of these classes is now split into subgroups, on the one hand, while, on the other, many individuals may be classed under two or more classes or sub-classes. Nevertheless, many difficulties and obstructions now face the workman who aspires to become an employer, who struggles to rise out of his class. John Mitchell believes that the workers are, as a rule, acting on the principle that they can not rise out of that class. For the vast majority it is once a wage-earner, always a wage-earner. The amount of capital now required to set up in nearly every business is large. Even the farmer who runs in debt for his farm, finds it almost impossible to pay off the mortgage from the profits of the farm in many sections of this country. The amount of money required to enter the iron and steel business is measured by hundreds of thousands or millions of dollars. Consolidation of business interests reduces the numbers of managers and superintendents. The great industrial concerns and the railroads are becoming large civil-service systems. A man must enter their employ in his youth, at the bottom, remain with the company year after year, gradually working into better-paid and more responsible positions. But he always remains an employee. The young man can no longer work hard for a few years, save a few hundreds or thousands of dollars, and then set up in business as an employer of others, many of whom will follow in his footsteps within a few years. The person who now accumulates a small amount of property is obliged to turn the management of it over to others. Investments in stocks and bonds, deposits

in savings-banks, insurance, and like modes of investing property, take the place of investment in landed property or in a business managed by the property owner. Management by proxy becomes the rule, not the exception. The corporate form of business requires the concentration of large amounts of property under the control of a chosen few. The savings-bank, for example, is merely a collective form of investing in which the investments are made by the banker rather than by the hundreds of small investors themselves. The discipline that comes from the care and management of property is lost on the great multitude of workers of to-day.

Also, coincident with this phenomenon is the above-mentioned change in the character of the multitudes of immigrants who are flocking to our shores. In the report of the Commissioner-General of Immigration, for 1904, an official of the bureau who has been conducting extensive investigations in Europe, writes from there as follows: "The average immigrant of to-day is sadly lacking in that courage, intelligence and initiative which characterized the European people who settled in the western states during the eighties." The personal initiative, adaptability and self-reliance of the American have ever been the pride of the nation; but the environment, business methods and opportunities which aided in the production of these characteristics are undergoing modification. Industry and commerce offer opportunity to only a few, for the development of these valuable traits; and immigration brings us a class of people who are also sadly deficient in these qualities.

"The machine process is a severe and insistent disciplinarian in point of intelligence. It requires close and unremitting thought, but it is thought which runs in standard terms of quantitative precision. Broadly, other intelligence on the part of the workman is useless, or it is even worse than useless."[3] Unfortunately under present conditions, the above quotation states what is true in many cases of subdivided labor. Extreme subdivision of labor has reduced the unskilled worker to the level of an automatic piece of machinery. Brains, ideals, everything which go to make up the real human being and to differentiate him from the automatic machine, are at a discount. The man becomes a "hand." The internal organization is now placed on a scientific, calculated basis. Time cards and exact methods of determining the cost of labor and material are now essential to every well-regulated business. Every step from the first displacement of the raw material until the finished product is in the hands of the consumer is carefully calculated.

The chief motive for subdivision of labor is given by the opportunity to hire unskilled, low-standard-of-living workers, at an extremely

[3] Veblen, "Theory of Business Enterprise," p. 308.

low wage. "Thus division of labor is, in the last analysis, nothing but one of those processes of adaptation that play so great a part in the evolutionary history of the whole inhabited world: adaptation of the tasks of labor to the variety of human powers, adaptation of individuals to the tasks to be performed, continued differentiation of the one and of the other."[4] But, if this differentiation is carried so far as to tie the individuals down to such a narrow routine as to prevent their rising in the scale of life, it is a bar to human progress. The immigrant is one of the causes of subdivision of labor. Where labor unions are strong enough to establish a minimum wage, some modifications may be looked for; but the question which society must face is: Can society afford to allow certain of its members to be reduced to the condition of human automatons? If it is held that certain classes in the community can not be improved or raised to a higher level, then indeed the caste form of society is treading close upon the heels of the American people.

Division of labor, perhaps even minute subdivision of labor, may be considered to be a permanent factor in industry. Modern industry is more productive, many times more productive, per worker, than the older, more simple forms; and as a result a shorter working day is allowed the worker. This grinding, unvarying, monotonous, joyless sort of working period should be balanced by broader social life, by better, more elevating use of leisure time. In short, as one's work becomes exact and narrowing, one's leisure time should bring variety and breadth of experience. The suffrage has been extended to practically all the male population over twenty-one years of age; but in order to exercise the franchise intelligently, as was recognized in the days of Plato and Aristotle, the citizen must have leisure time to study and discuss the social and political problems of the day. If this leisure time is not properly or wisely utilized; the "boss" and the "machine" flourish. The great multiplicity of clashing interests also offers opportunity for the shrewd and unscrupulous politician to play interest against interest, and to win political control and personal gain through careful manipulation. In any industrial democracy, the problem of the utilization of leisure becomes one of the important and vital problems.

Looking at education from a purely economic point of view, aside from ethical considerations, the aim should be to develop not only more efficient producers, but also more efficient consumers. All men must be considered from the side of consumption as well as of production. The end and aim of normal economic activity is consumption of economic goods. Other things being equal, consumption should be directed toward those articles which the country is best adapted to produce; it should also be directed away from the excessive demand for the raw

[4] Bücher, "Industrial Evolution," p. 299.

and crude economic goods, toward a greater variety in quantity and quality of demands. As Clark has shown, the tendency of dynamic economics, as seen from the purely economic point of view, is toward variety in consumption and specialization in production. But after a certain point is past specialization in production tends to prevent greater variety in consumption. These economic considerations, as well as those of an ethical or social nature, set bounds beyond which specialization ought not to pass. This limit is not fixed and invariable. For example, the man who has an avocation, who utilizes his leisure in such a way as to broaden his view of life, so as to exercise many different sets of muscles and brain cells, may specialize his work much more minutely without individual detriment or economic and social loss, than the man who talks shop, or does nothing to diversify his tastes or to open up new lines of thought and action, during his leisure hours. In the terms employed by the economist, the ideal point of equilibrium is where the descending curve of the social value of the products due to additional subdivision is met by the ascending curve of disutility due to long-continued and narrow specialization on the part of the individual members of society. Other things remaining the same, the additional products which come into being through increasing subdivision, gradually diminish in value as increment after increment is added, according to the well-known law of diminishing returns; and on the contrary the detriment to society as a whole increases as individuals are forced into narrower and narrower rounds of duty.

Ethical considerations lead directly and unequivocally to the conviction that men must not be treated as machines, that the true end and aim of industry is the production of men, not the multiplication of profits. True long-run economic aims coincide with ethical ideals. As Walt Whitman has taught us: "Produce great men, the rest follows." Primitive industry was always a means to an end which was plainly seen; it was never an end in itself. It has remained for modern times to heap up complexity, confusion, and cross-purposes until the fundamentals have been hidden from view. When the methods of modern complex industry come into collision with the true economic and ethical demands of society, the former must be modified. It is one of the functions of education to harmonize the demands of these two apparently conflicting and opposing forces. It should so train the members of society as to allow the greatest possible advantage to be taken of efficient productive methods consistent with the welfare and best development of the individual members of society of all classes and conditions.

Both the internal and external organization of industry now tend to remove variety, irregularity, risk, chance and speculation. The

business of the future calls for the manager and the administrator rather than the speculator or the promoter, for the steady, routinized, narrowly specialized worker rather than all-round men so familiar in the early industrial history of the United States. The traits of the pioneer, the backwoodsman and the hunter, those traits due to varied and changing experiences of the early settler, continue, however, and are transmitted from generation to generation long after the stimuli which produced them have ceased to act and have been overwhelmed by the rising tide of civilization. If modern life offers inadequate opportunity in the ordinary course of daily life for the expression of these inherited impulses, if they are inhibited from all beneficial or desirable expression, they will find expression in abnormal or undesirable ways. Gambling, sport of all kinds, drinking, carousing, are some of the many forms in which these inhibited traits find a vent. The assimilation of the recent immigration will dilute and diminish the strength of these characteristics; but they should not be smothered and cast aside, they should be utilized and turned into new and modern channels of activity.

Mr. John A. Hobson in a recent article touches upon this point. "The factory employee, the shop assistant, the office clerk, the most typical members of modern industrial society, find an oppressive burden of uninteresting order, of mechanism, in their working day. Their work affords no considerable scope for spontaneity, self-expression and the interest, achievement and surprise which are ordinary human qualities. It is easily admitted that an absolutely ordered (however well ordered) human life would be vacant of interest and intolerable; in other words it is a prime condition of humanity that the unexpected in the form of happening and achievement should be represented in every life. Art in its widest sense, as interested effort of production, and play as interested but unproductive effort, are essential."[5] If modern industrial and commercial life is being placed upon a stable, sure, scientific, calculable basis, if chance and luck are being replaced by skill and efficiency, if routine and dead uniformity are replacing all-round effort and variety, if the home environment is becoming more monotonous and artificial; other social institutions must furnish pleasurable change and variety. If elevating institutions as the school or the church do not cope satisfactorily with the situation; other much less desirable ones will, and the spirit of gambling, of riotous living, of carousal, of living for the sake of sport, will enter society and take a firm hold. Old instincts are not easily eradicated; education must never overlook them. The recent additions and contemplated additions to our educational system are the concrete results of some of the

[5] *International Journal of Ethics*, January, 1905.

attempts which have been made to cope with the question in a more or less intelligent manner.

The entrance of the United States and other important industrial nations upon a policy of commercial expansion, the growth of imperialism and the prevalence of the desire to exploit the less industrially progressive nations, mark the beginning of a new epoch in our national life. Specialization of industry and subdivision of labor now assume new aspects. Capital becomes international; while labor still remains upon a national basis. Mr. Hobson and others have pointed out that the backward nations will now assume the place hitherto occupied by the great mass of the unskilled in the home country. Humanitarian and democratic tendencies are in danger of receiving a check. Capital in a new, rapidly developing country finds opportunity for investments in improvements; but in a more highly developed, but still progressive country, it is obliged, unless there are opportunities for investments in foreign countries, to seek investment in directly productive enterprises which produce articles for the consumption of the great mass of the people. If there is no opportunity for foreign investment of capital, industrial progress will necessitate an improvement in the consumptive power of the masses. Economic and ethical aims begin to draw into closer relationship. The possibility of enormous investments of capital in South America and Asia is something which threatens to affect the industrial, social and educational welfare of the American people. "Once encompass China with a network of railroads and steamer services, the size of the labor market to be tapped is so stupendous that it might well absorb in its development all the spare capital and business energy the advanced European nations and the United States can supply for generations."[6] China and the Chinese workers are a danger because of the low standards of living which prevail in the Asiatic nation, and the consequent ease with which the Chinese people may be exploited. If increased manufacturing and commercial activity in China is not accompanied by a corresponding increase in the standard of living, the American farmer and the American workman are doubtless imperilled by the situation. The educational movement of the last two or three decades is essentially a working class movement; and its future is bound up in the welfare of the industrial and agricultural classes.

[6] Hobson, "Imperialism," p. 334.

THE DAWN OF QUADRUPEDS IN NORTH AMERICA

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IN the early days of the physical sciences one who gave a common-sense interpretation to a phenomenon of nature was looked upon as dissenting from the accepted interpretation of things. It pleased the people of the early days of science to regard natural phenomena as something wonderful, as a divine creation or as something beyond the comprehension of the human intellect. It has been less than two centuries since men began to emerge from under this pall. The advance made in science constitutes one of the wonders of the age. It is the purpose of this essay to record the progress of investigation in one line of scientific research, and that is the one which leads up to a knowledge of the ancestry of one group of the vertebrates.

The early observers of nature had curious suppositions in regard to the nature of fossils. They regarded these objects, which were common, as of various origins. Some claimed that they arose spontaneously in the rocks, others were of the opinion that they arose from germs which had fallen from heaven, but the large majority believed the fossils to be the remains of "an accursed race" whose existence had been ended by the Noachian deluge. Early in the seventeenth century collectors of natural objects became familiar with certain bodies which were known as "glossopetræ." They were embedded in the rocks and the manner of their entombment was a matter of considerable dispute. In the first half of the seventeenth century, Fabio Colonna had tried to convince his contemporaries that the "glossopetræ" were nothing but shark's teeth. His arguments failed to carry conviction, however. It was not until 1669 that Steno, a Dane by birth, though a teacher in the schools of Florence, Italy, demonstrated by the dissection of a common shark's head that the "glossopetræ" and the teeth of the shark were identical. These results he published in a quaint little volume entitled "De Solido intra Solidum naturaliter contento."[1] This was the first application of the modern method of paleontological research to the study of objects contained in the rocks. Later Cuvier continued and extended the researches of Steno and from the time of the famous investigator, Cuvier, to the present, our knowledge of the objects entombed in the rocks has progressed rapidly.

Modern researches have carried our knowledge of the distribution

[1] Huxley, T. H., 1881, "Science and Hebrew Tradition Essays," p. 29.

and relationships of animals farther and farther back into geological time. There was a time, not many decades ago, when people knew nothing of the animals of the ancient days. During the life of Cuvier the knowledge of extinct animals had not progressed much farther back into geological time than the Cretaceous or Jurassic. It was just four years before his death that Jaeger made his important contribution to the Triassic fauna of Europe by the description of the remains of *Mastodonsaurus,* which he had in 1824 described as *Ichthyosauri.* Subsequent researches by a host of observers have carried our knowledge of animals into an antiquity which had not been expected.

The animals which it is our purpose to treat here are the ancestors of the modern Amphibia. There are few groups of vertebrates whose phylogeny is more obscure than that of our common toads, frogs and salamanders. It is the popular idea that these animals are unknown back in geological time, but that they are of a rather recent origin. As a matter of fact the present-day amphibians are the descendants of the oldest group of vertebrated animals with the exception of the fishes. Our knowledge of the fishes begins near the dawn of animal life on earth, and their remains are preserved in the rocks of the Ordovician age, just west of Cañon City, Colorado, and in the Big Horn Mountains, Wyoming. Our knowledge of the amphibians begins just two ages later, and in the Devonian rocks of Pennsylvania are found the earliest traces of quadrupeds on earth. These evidences consist in footprints found by Isaac Lea in 1849 and the announcement of his discovery was given to the British Association for the Advancement of Science by Buckland in that year. These footprints represent a rather large animal which may have attained a length of several feet. The footprints were found impressed in the " Old Red Sandstone " of Pennsylvania which forms a part of the Catskill formation of that state. Marsh, forty-seven years later, announced the discovery of similar footprints from the same horizon and near the same locality but does not mention the discoveries of Lea. From these tracks in the Devonian to the deposits in the Allegheny series of the Pennsylvanian our knowledge of the Amphibia is a blank. There is not a trace recorded of any amphibians in the rocks of the Mississippian or in the Pottsville of the Pennsylvanian.

In the Allegheny series, there are several deposits in the United States, and probably one in Canada, which have produced remains of the early quadrupeds. The principal localities are in Illinois, Pennsylvania and Ohio. From the last named state great numbers of these paleontological treasures have been recovered and are preserved in the museums of the east. The most interesting place which has kept for us a record of the amphibian life of this far-off time is a deposit of coal in the eastern part of Ohio in the northern part of Jefferson county.

These deposits are in the form of a thick bed of coal which has been opened up by modern industry which has cast aside as useless the blocks on which are preserved the priceless relics of the creatures of this bygone time. There have been great numbers of these blocks of coal collected by geologists, but in all probability the greater part of the animal remains preserved in the coal has gone to furnish heat for the people of the region.

The animals, which have been obtained from the old Diamond mine near the village of Linton, Ohio, are imbedded in the coal which formed from the vegetation growing on the shores of the lake in which the coal accumulated.[2] This old lake was probably of but limited extent and may not have measured more than six miles in its greatest diameter. In this lake lived and died for ages the animals whose remains represent the first recorded appearance of quadrupeds on the earth. There are, to be sure, deposits in Illinois which are of contemporaneous age, but so far only five specimens of amphibia have been discovered in these deposits, so they are hardly to be taken into account when compared to the hundreds of specimens obtained by Dr. J. S. Newberry from the Linton locality. The animals which disported themselves in this old lake, at their death fell to the bottom and their remains, what was left of them after their former companions had feasted on their bodies, were covered with the mud and vegetation which drifted in upon them. Thus they are preserved to us.

The student of these remains finds them greatly different from the amphibians of to-day. There were some forms which were large, but the majority of them were small. Some may have reached a length of ten feet while a great many did not exceed six inches and a few were less than five in extent. There is one little form from Illinois, to be described further on, which barely attained a length of two inches in the adult state. Some of the Amphibia from the Linton mines represent snake-like forms with the proportions of the modern whip snake of the western plains, though not with its dimensions. Others more nearly resembled the modern lizards and this resemblance was carried to the extent of the possession of strong teeth and clawed digits. There was no osseous carpus and tarsus, however, so that they are distinct from the lizards structurally. Still other of these early quadrupeds must have resembled the modern crocodiles in appearance and a few may have attained nearly the dimensions of these forms. There were forms which were partially protected by hard dermal plates, at least on some parts of the body. Some, like the fishes, had rounded scales which covered the entire body, while a few appear to have been entirely naked. All the forms appear to have possessed the ventral armor of dermosseous rods or scutes which protected the abdomen much as the abdomen of the *Sphenodon* of New Zealand is protected to-day.

[2] Newberry, J. S., 1889, Monograph U. S. G. S., Vol. XVI., p. 211.

When in the later ages of the existence of this old lake its waters became filled with vegetation and it had acquired the characters of a marsh there came a disturbance in the earth's crust and the lake was again submerged, and on its bottom was formed the thick stratum of good coal which is now known to geologists as the "Ohio No. 6." This coal was formed over the graves of the earliest quadrupeds. Here through the vast stretches of geological time they lay in their coaly bed. After many, many eons of time the descendants of animals which had been their contemporaries came with tools fashioned with their fore feet to dig out the coal to keep their naked bodies warm. These were men and to these miners we owe a debt of gratitude for thus bringing to light these treasures of the earliest quadrupeds.

There was a man in the days when these coal mines were being worked who appreciated the opportunity of collecting the remains of these creatures and he deserves far more credit than the miners who delved in the ground for the coal. This was Dr. J. S. Newberry, whose name is to be ever associated with the first investigators into the history of the primitive quadrupeds of this continent. Through his knowledge of the geology of the region in which the mine was located he realized, as no other did, the importance of gathering these remains as rapidly as possible. The result was worthy of the exertion. The mines have now long since been deserted, the village of Linton has gone out of existence and even the spot where the mines were located is difficult to find, so Dr. Hussakof tells me. Newberry's collection of the early quadrupeds is now in the American Museum of Natural History of New York City, and it will stand as a monument to the zeal of one of the early investigators into the "Eotetrapoda" of North America. Newberry's collections have, for the most part been described by Cope, who has done more on the morphology of the extinct Amphibia than any other investigator in North America.

Dr. Newberry found the first recognized amphibian in the Linton deposits in 1856. The next year Dr. Wyman read a note on the specimen before the meeting of the American Association and the next year he published a description of the form under the name *Raniceps lyelli.* It was necessary to change the name *Raniceps,* so ten years later Dr. Wyman proposed in its stead the term *Pelion* and the form is still known as the *Pelion lyelli* Wyman. This is perhaps one of the most extraordinary of all of the Amphibia which have came from these deposits (Fig. 1). It was thought by Wyman, and later by Cope, that the form had the characters of the modern frogs and in its general appearance it certainly shows great resemblances to the modern frogs, especially in the shape of its head and the length of the hind leg, which Cope seems not to have observed. Among the other forms collected by Newberry is the form shown in Fig. 2. One half of the slab containing

FIG. 1. THE TYPE OF *Pelion lyelli* WYMAN FROM THE CARBONIFEROUS OF OHIO. In the collection of the American Museum. Natural size.

the lesser part of the skull went to Dr. Newberry, and in some way the other half of the slab containing the major portion of the cranial elements was obtained by Mr. W. F. E. Gurley and it is now in the collection of the University of Chicago. The illustration is made from the latter specimen. This form is peculiar in the possession of horns which projected backward over the neck. Jaekel suggests that these horns were for the protection of the external gills, but the Microsauria, so far as we know, had no gills, at least in the adult state.

Geologically the record of the amphibians, as it has been given, is the correct one, but chronologically it is not. Long before a single specimen had been taken from the Linton beds Sir William Logan, in 1842, found evidences of amphibians in the Carboniferous of Nova Scotia in some footprints later named by Dawson *Hylopus logani*. These footprints Logan took with him to London and submitted them to the famous paleontologist, Sir Richard Owen, who unhesitatingly pronounced them to be "reptilian." Logan's discovery constitutes the earliest recognition of amphibians in the Carboniferous. A few years

later Sir J. W. Dawson and Sir Charles Lyell in breaking apart one of the stumps of the large Sigillariæ came across some interesting vertebrate remains. When the announcement of this discovery was given to the Geological Society of London, the president or secretary remembered a skull which Dawson had sent in three years previously and which had lain in the collection of the society all of this time. Dawson had been delayed one day at Albion, Nova Scotia, and in order to while away the time between trains looked over a pile of rubbish from a coal mine near by. In so doing he split open a large slab of shale in which he found a nearly perfect skull of some unknown animal which he thought might be a fish. This he sent to the Geological Society with other specimens, and it was described in 1853 by Sir Richard Owen as *Raphetes planiceps*, and its relationships were shown to be with the Amphibia. There have been but few remains discovered since at this locality, although it was frequently examined by Dawson.

FIG. 2. THE TYPE OF *Stegops divaricata* COPE FROM THE CARBONIFEROUS OF OHIO. In the collection of the University of Chicago. Natural size.

FIG. 3. THE SPECIMEN OF *Amphibamusgrandiceps* COPE FROM THE MAZON CREEK BEDS OF ILLINOIS. In the collection of Mr. L. E. Daniels of La Porte, Indiana. Natural size.

For many years after 1853, Dawson continued his researches into the Amphibia of the Joggins section in Nova Scotia, and he has left us a great amount of knowledge which he collected into his "Acadian Geology" and into his "Air-Breathers of the Coal Period." The forms described by Dawson differed in an essential respect from those discovered in the United States. The animals whose remains occur in the hollow sigillarian stumps in the Joggins deposits, seem to have all

been of terrestrial habits, and Dawson frequently speaks of them as "lizard-like" and his restorations of some of the forms, though based on very scanty remains, indicate forms which would be taken for modern lizards. While his restorations are in part fanciful, he has given, in the main, an accurate idea of the animals as indicated by the remains preserved in the old stumps of the swamp in which the animals lived.

Cope's researches into the structure of the early quadrupeds constitute an interesting chapter in the history of the early vertebrates. His researches on the extinct Amphibia began in 1865 by the publication of the description of the form known as *Amphibamus grandiceps*, from the Mazon creek beds of Illinois. This specimen was loaned to the Illinois Geological Survey for Professor Cope to study by Mr. Joseph Even of Morris, Illinois. After Cope's description of the form, the specimen was returned to Mr. Even and, as Mr. L. E. Daniels tells me, it was later destroyed by fire. Mr. Daniels has recently been kind enough to allow me to study a specimen of this form in his collection, the only one, so far as I am aware, now in existence (Fig. 3). The peculiar characters of this form are the possession of sclerotic plates in the eyes and the possession of long curved ribs which have been recently described by Dr. Hay from this same specimen. A specimen of another species from his same deposit has been in the Gurley collection for nearly thirty years. Dr. Newberry saw it when he studied Mr. Gurley's fishes and said in a note that Professor Cope should see it. It was never sent to Cope, however, and it is described elsewhere by the writer as *Micrerpeton caudatum*, gen. et sp. nov. This is a very interesting form, since it shows the impression of the fleshy tail (Fig. 4). On this tail impression are preserved many important structures heretofore unknown for the Branchiosauria to which the form belongs. As such it represents not only the earliest geological evidence of the group, but it is the first appearance of the Branchiosauria in the discoveries in the early quadrupeds in North America. It is a typical branchiosaurian and as such belongs to the family in which the *Branchiosaurus* of Europe is placed.

Between the years 1865 and 1897 Cope continued his investigations on the early quadrupeds and his results are to be found in the proceedings of several learned societies. He early recognized the unusual characters of the Carboniferous fauna, and his many papers attest his interest in the forms which constitute it. He has described all but two of the known Carboniferous species from the deposits of the United States. Among the many peculiar types of amphibians described by Cope none is more bizarre than the form from the Permian of Texas known as *Diplocaulus magnicornis* Cope. This peculiar form has been widely described and commented on. Its affinities are clearly with the Microsauria, and it is one of the latest representatives of that group

FIG. 4. THE TYPE OF *Micrerpeton caudatum* MOODIE FROM THE CARBONIFEROUS OF MAZON CREEK, ILLINOIS. In the collection of the University of Chicago. Twice natural size.

known to us. It is peculiar in the wide horn-like expansions of the skull (Fig. 5). There is no pineal foramen in the dorsum of the skull and it lacks a few of the characters of the other amphibians known from this region.

Interest in the early Amphibia has not slackened in the later years and there have been many contributors to the knowledge of the early forms. There are at present nearly seventy-five species of Carboniferous Amphibia known from North America and as many have been recorded from the Carboniferous and Permian of Europe; many more undoubtedly await discovery. The forms do not differ greatly in their structure in the two continents and each has relatively the same amphibian fauna, although the North American fauna is perhaps somewhat older than the European one. Certainly the Branchiosauria are found

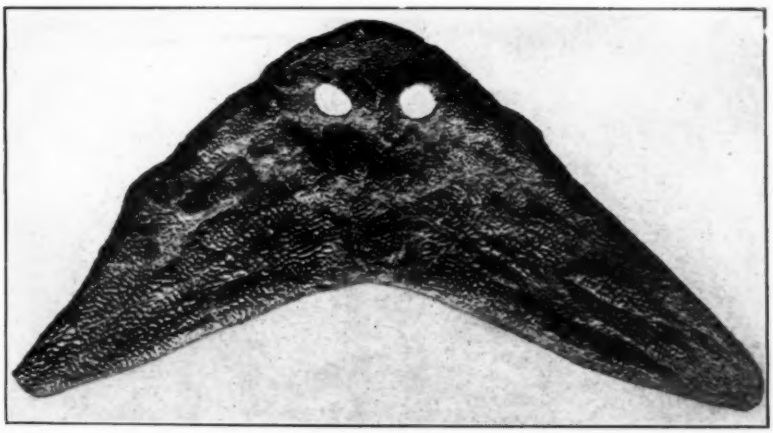


FIG. 5. A SKULL OF *Diplocaulus magnicornis* COPE FROM THE PERMIAN OF TEXAS. In the collection of the University of Chicago. Three tenths natural size.

here in older rocks than in Europe. Among the many forms known may be mentioned some with a peculiar type of vertebra in several allied genera found in Ireland, western Europe and North America; some with fish-like scales over the whole body found in Ireland and Ohio; the presence of the snake-like forms in Ireland, England, western Europe and Ohio and the presence on the continents of Europe and North America of the Branchiosauria already referred to. All of the types of amphibians possess the peculiar ventral armature which was arranged in a chevron pattern over the belly, breast, throat, and even extended, in some cases, out on the limbs.

The earliest quadrupeds, as we know them, form highly specialized groups of organisms which had become differentiated into five distinct lines by the close of the Carboniferous. We must await the progress of discovery to unfold for us the nature of the most primitive quadrupeds from which the earliest known forms have sprung.

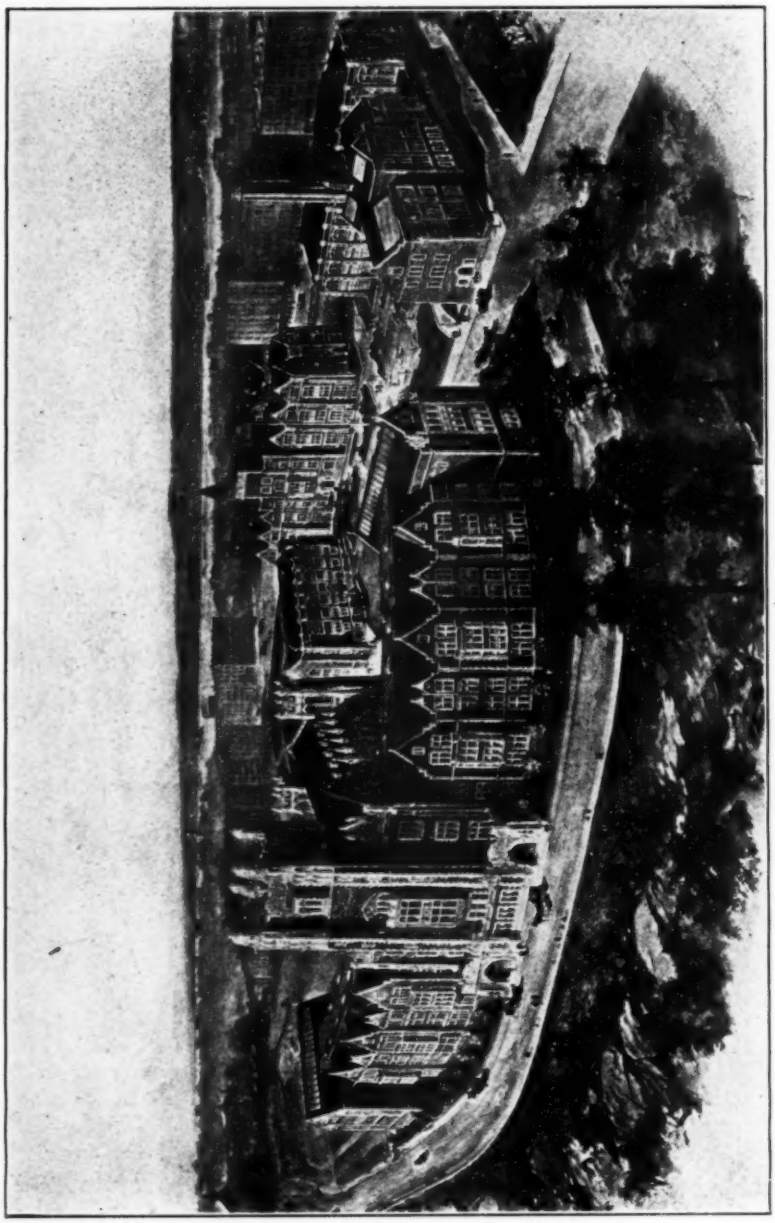
THE PROGRESS OF SCIENCE

THE NATIONAL ACADEMY OF SCIENCES AND THE AMERICAN PHILOSOPHICAL SOCIETY

THE scientific meetings held at Washington and Philadelphia during the third week of April offered programs of interest and were pleasant events for those able to attend them. Neither of these societies is exactly in touch with democratic institutions or is able to adjust itself to the differentiation of science, but they have shown in recent years more vitality than might have been expected. The National Academy has taken steps to make its scientific programs of greater general interest and has enlarged its membership, so that instead of at most five new members elected annually there may now be ten. The American Philosophical Society has within the past few years resumed to a certain extent the national character which it possessed when Philadelphia was the chief scientific center of the country. Its annual general meetings bring together a considerable group of men of science from different parts of the country, and the meeting two years ago to celebrate the bicentenary of the birth of Franklin, its founder, was probably the most elaborate and successful scientific celebration ever held in this country.

At the meeting of the National Academy in Washington there were twenty papers on the program, twelve by members and eight on introduction. Several of the papers were elaborately illustrated with the lantern, the most noteworthy slides being the extraordinary enlargements of photographs of cells, showing the chromosomes on which the determination of sex depends, made by Professor E. B. Wilson, of Columbia University. Other illustrated papers were presented by Professor W. M. Davis, of Harvard University, showing standard land forms for a proposed international atlas; by Professor W. B. Scott, of Princeton University, on the age of certain beds in Patagonia, with restorations of Santa Cruz mammals by Mr. C. R. Knight, of the American Museum of Natural History, and by Professor E. L. Mark, of Harvard University, on the Bermuda Biological Station at Agar's Island. Mr. Alexander Agassiz gave an account of the pelagic fauna of Victoria Nyanza and of the elevated reefs of Mombasa and the adjacent coast, and Professor T. C. Chamberlin, of the University of Chicago, described atmospheres supplementary to the one ordinarily considered. Then there were more technical papers. That such papers can be made attractive was shown by the account by Professor W. G. MacCallum, of the Johns Hopkins University, of the parathyroid glands in their relation to tetany and calcium metabolism, and by the paper of Professor F. R. Moulton, of the University of Chicago, on the application of periodic solutions of the problem of three bodies to the motion of the moon. Other events of the meeting were a visit to the newly constructed and admirably equipped geophysical laboratory of the Carnegie Institution, an illustration of which was shown in a recent issue of the MONTHLY, and a lecture on solar research, given under the auspices of the Smithsonian Institution by Professor George E. Hale, of the Mt. Wilson Solar Observatory.

The new members elected were: Edwin Brant Frost, director of the Yerkes Observatory, University of Chicago; William E. Storey, professor of mathematics, Clark University; Edward F. Nichols, professor of physics,



NEW BUILDINGS OF THE COLLEGE OF THE CITY OF NEW YORK.

Columbia University; W. F. Hillebrand, chemist in the U. S. Geological Survey; Wm. B. Clark, professor of geology, the Johns Hopkins University; Whitman Cross, geologist, U. S. Geological Survey; E. G. Conklin, professor of zoology, University of Pennsylvania, professor-elect of biology, Princeton University; Theobald Smith, professor of comparative pathology, Harvard Medical School; Simon Flexner, director of the laboratories of the Rockefeller Institute for Medical Research.

At Philadelphia the program was twice as long and even more diverse, as the Philosophical Society includes in its scope the historical and philological sciences. Of the forty-two papers presented, it is possible to mention only three or four. Professor C. S. Minot, of Harvard University, discussed the differentiation of the protoplasm of the cell in its relation to reproduction; Professor H. S. Jennings, of the Johns Hopkins University, described experiments on inheritance among the protozoa. Dr. C. B. Davenport, of the Cold Spring Harbor Laboratory, considered the extent to which Mendelian inheritance obtains; and Professors E. T. Reichart and A. P. Brown, of the University of Pennsylvania, showed that the crystals of oxyhemoglobin from the blood of different genera differ, and that even species can be recognized by the crystals. Dr. H. F. Osborn, president of the American Museum of Natural History, gave a lecture on the results of the Museum's explorations in the Fayûm desert of northern Egypt, preceding a reception in the hall of the Pennsylvania Historical Society, and there was a concluding dinner with speeches by the Chinese minister and others.

DEDICATION OF THE NEW BUILDINGS OF THE COLLEGE OF THE CITY OF NEW YORK

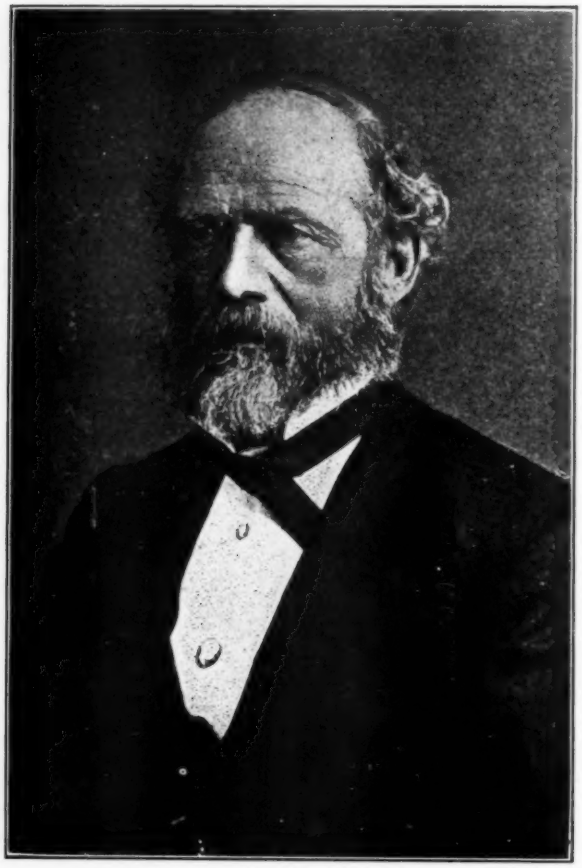
THE beautiful and well-planned buildings of the College of the City of New York were dedicated with ceremonies adequate to the event on the fourteenth of May. As shown in the accompanying sketch, drawn by Mr. Richard Rummell, they form a group of buildings such as has rarely if ever before been dedicated at one time to academic purposes. The situation on St. Nicholas Heights equals that of Columbia University, a mile to the south, and is less likely to be marred by the encroachments of shops and apartment houses. An institution of this character, which embodies in its external impressiveness as well as in its work and aims civic duty and pride, represents the best ideals of modern civilization.

The College of the City of New York is maintained by the people of the city for the education of its young men, and is in some respects unparalleled in this country or elsewhere. Philadelphia and Baltimore have high schools of nearly college rank, and Cincinnati has a municipal university, and these four institutions represent a movement likely to become general throughout the country. The College of the City of New York, in view of what it has already accomplished and in view of the great population and wealth of the city, seems destined to take the lead in an educational advance likely to be as important for the next generation as the evolution of the state universities has been for the present generation.

LEWIS HENRY MORGAN

UNDER the auspices of the National Academy of Sciences there are published biographical memoirs of its deceased members. These documents are of value for the history of science in this country, but are not as widely circulated or as well known as they should be. Just published is a memoir of Lewis Henry Morgan by Mr. W. H. Holmes, chief of the Bureau of American Ethnology, which from several points of view is of special interest.

Morgan, who was born in Aurora,



LEWIS HENRY MORGAN.

N. Y., in 1818, and died in Rochester in 1881, was by profession a lawyer and man of affairs, interested in the first development of the railway system in the middle west, a member of the legislature, both house and senate. He was thus the type of man more usually found among the hereditary upper classes of Great Britain than in our industrial democracy. In view of the increasing specialization of science, there appears to be but little place for the amateur and perhaps this is not to be regretted. But those who begin as amateurs and become serious students with science for their main concern, are selected from large numbers in accordance with interests and talent, and the threatened disappearance of such a group is a serious loss to science.

As a young man Morgan became interested in the League of the Iroquois Indians and an intimate friend of Hasa-no-dû-da, or Ely S. Parker, a Seneca Indian, later commissioner of Indian affairs. He was adopted into a clan of the Seneca nation and admitted fully to its society. His intimate knowledge resulted in the publication of a book on "The League of the Iroquois," the first scientific account of an Indian tribe. Morgan then became well acquainted with the Algonquins and other families and prepared his volume on "Systems of Consanguinity and Affinity of the Human

Family." This was followed by his important work on "Ancient Society," which treats the growth of intelligence through inventions and discoveries, of government, of the family and of property. He was also the author of works on "Houses and House-life of the American Algonquins" and on "The American Beaver."

Morgan bequeathed most of his property to the University of Rochester for the higher education of woman. His anthropological works led him to say: "Democracy in government, brotherhood in society, equality in rights and privileges, and universal education foreshadow the next higher plane of society to which experience, intelligence and knowledge are steadily tending. It will be a revival, in a higher form, of the liberty, equality and fraternity of the ancient gentes." Morgan was not only a pioneer and leader in the study of the American Indians, but one of the founders of ethnology, a science likely to become dominant in the course of the present century.

THE SARGENT ANNIVERSARY MEDAL

THE former students and friends of Dudley Allen Sargent, A.M., Sc.D., M.D., director of the Hemenway Gymnasium, Harvard University, have presented him with a bronze medallion. The medallion, designed by Dr. R. Tait McKenzie, has above the face of Dr. Sargent the words "Dudley Allen Sargent, Pioneer in Physical Education, 1907," while on the reverse is a row of five Harvard seals below the words, "A Recognition by his Friends and Students." Two hundred and thirty persons contributed to the medallion fund. A plaster model of the medallion and a bound volume containing the autographs of the contributors to the fund were presented to Dr. Sargent by Dr. Luther Halsey Gulick at the twenty-fifth commencement of the Sargent Normal School of Physical Training held in Sandars Theater, June 1, 1907. The bronze medallion was finished recently and presented to Dr. Sargent. The Sargent medallion committee is having struck a limited number of copies of the medal. These are to be presented to President Roosevelt, Secretary William Taft, Major General Bell, Governor Curtis Guild and Booker T. Washington, who were all students under Dr. Sargent.

SCIENTIFIC ITEMS

WE record with regret the death of Dr. Robert Chalmers, of the Canadian

MEDAL STRUCK IN HONOR OF DR. DUDLEY ALLEN SARGENT.

Geological Survey, and of Professor Franz von Leydig, the eminent zoologist of Bonn University.

THE body of Emmanuel Swedenbourg has been removed from the Swedish church in London, where it was buried on his death in 1772, and taken by a Swedish man-of-war to Stockholm, where it will be interred.—By the will of Lord Kelvin, Lady Kelvin is appointed sole executrix, and all his property is bequeathed to her. According to the inventory, the value of the property is over $800,000.—The bill providing a pension of $125 monthly each to the widows of Drs. James Carroll and Jesse W. Lazear has passed the congress by a unanimous vote.

PROFESSOR FREDERICK F. JONES, dean of the College of Engineering and Mechanical Arts in the University of Minnesota, has been elected dean of the academic faculty of Yale University. Professor Jones graduated from Yale College in 1884 and has been connected with the University of Minnesota since 1885.—At the University of Wisconsin Professor Carl C. Thomas, now head of the department of marine engineering of Cornell University, has been elected to the professorship of steam engineering made vacant by the death of Storm Bull.

THE Boston Society of Natural History has awarded the Walker grand honorary prize of one thousand dollars to Dr. Grove Karl Gilbert, of the United States Geological Survey. This award is made once in five years under the terms of the will of the late William Johnson Walker, a benefactor of the society, "for such scientific investigation or discovery in natural history as the council may think deserving thereof; provided such investigation or discovery shall have first been made known and published in the United States of America." The previous recipients of the Walker grand prize have been: Alexander Agassiz, Joseph Leidy, James Hall, James D. Dana, Samuel H. Scudder and Joel A. Allen.—The Rumford medal of the American Academy of Arts and Sciences has been awarded to Dr. Edward G. Acheson, of Niagara Falls, for his work with the electric furnace.—Dr. William H. Walker, professor of technical chemistry at the Massachusetts Institute of Technology, has been presented by the New York Section of the American Chemical Society with the Nichols medal.

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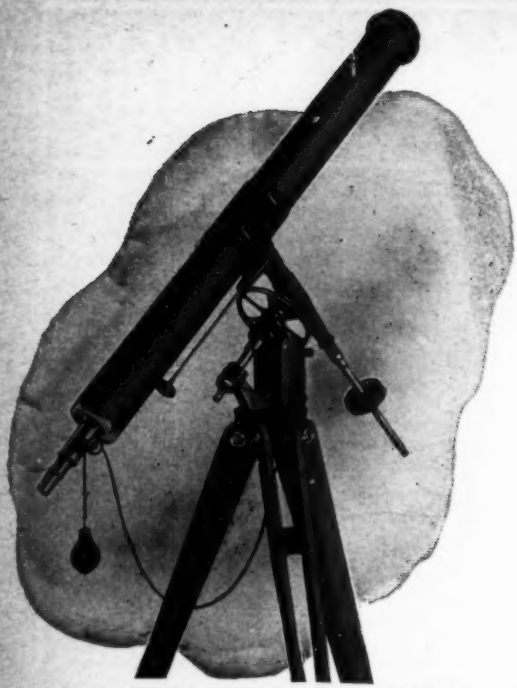

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